Education Reform and Development, 2024, Volume 6, Issue 4
https://ojs.bbwpublisher.com/index.php/ERD
Online ISSN: 2652-5372
Print ISSN: 2652-5364

Exploration of Practical Teaching Mode of Electrical Control and Programmable Logic Controller Application Based on Project Teaching Method

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Abstract: In today's prosperous industrial era, training electrical control personnel to meet the needs of the industry remains one of the important tasks of colleges and universities. How to effectively cultivate electrical control personnel has become an unavoidable issue for industry and colleges and universities. Aiming at the problems existing in the current teaching mode of electrical control and programmable logic controller (PLC) application, this paper proposes a new teaching mode based on the project teaching method. The methodology aims to increase student engagement, deepen understanding of theoretical knowledge, and reinforce the development of practical skills. Through the implementation of the project teaching method, it is expected to effectively cultivate electrical control talents to meet the needs of the industrial control industry and inject new vigor into the development of modern industry.

Keywords: Project teaching method; Electrical control; Programmable logic controller

Online publication: May 20, 2024

1. Introduction

Electrical control and programmable logic controller (PLC) application has always been the main course in all institutions of higher learning, and it is also a classic theory-to-practice course. This course requires students'high practical skills. At the same time, there is an urgent demand for PLC technicians in the industrial control industry, so this course has always been highly valued. To meet this demand, many colleges and universities have begun to revisit traditional methods of teaching electrical controls and have made PLC a key component of their instruction. This shift not only reflects the widespread acceptance of PLC technology in industry but also the close alignment of education with industrial needs [1]. In the field of electrical control, the complexity of control logic continues to increase as technology advances and industrial needs evolve. Traditional relay systems perform well in simple logic control. However, its limitations become increasingly apparent in the face of growing complexity. To meet this challenge,

programmable logic controllers emerged as the new alternative to relays for complex logic control. The core of a relay system lies in the physical switching of circuits to complete logical control. However, as the demand for control increases, the number of relays required increases dramatically and the hardware circuits become extremely complex. This not only increases the failure rate of the system but also makes maintenance and management extremely difficult. In addition, it is challenging to implement advanced control functions such as proportional-integral-derivative (PID) control and analog signal conversion with relay systems. In contrast, PLC offers greater flexibility and scalability through software programming for logic control. It integrates a variety of advanced functions such as PID control, analog signal conversion, arithmetic operations, etc. These functions are capable of meeting complex control requirements. At the same time, the PLC adopts a modular design, which can be flexibly configured according to the demand and reduces the complexity of the hardware circuit [2,3]. In addition, PLCs have powerful communication capabilities that allow them to connect and communicate with a variety of devices to transfer and share data, since PLC and relay have strong inheritance and complementarity. At present, many institutions of higher learning will teach the two technologies together, the course name is "Electrical Control and PLC Applications."

2. Existing problems of electrical control and PLC application teaching models in universities

Traditional teaching methods have many disadvantages when teaching electrical control and PLC applications. For example, traditional teaching methods tend to favor theory [4]. Teachers spend a lot of time explaining principles, circuit diagrams, and programming languages while students are confused by these abstractions. This teaching method ignores the practical application of PLC technology. This results in students not being able to effectively apply what they have learned when faced with a real electrical control system [5]. Traditional teaching methods also rely too much on classroom lectures and lack interactive and practical sessions. This single teaching method fails to stimulate students' enthusiasm and interest in learning. Moreover, students are unable to deepen their understanding of electrical control and PLC applications through hands-on practice [6]. Electrical control and PLC applications are rapidly evolving fields. There are a lot of new technologies and equipment emerging constantly. However, the content of traditional textbooks often fails to keep up with the pace of technological updates. This results in students learning knowledge that may be outdated. This not only affects students' learning effectiveness but also restricts their future career development. At the same time, traditional teaching methods often lack operational experience in real projects. Although students can carry out some basic experimental operations in the laboratory, these experiments are often far from the real working environment. Due to the lack of practical project experience, students may not be able to quickly adapt to the working environment of the enterprise after graduation or solve the problems encountered in real work [7]. In summary, the traditional teaching method of electrical control and PLC application has the disadvantages of disconnecting theory and practice, single teaching method, lagging content of teaching materials, and lack of practical project experience. In order to cultivate electrical control and PLC technology talents who are more in line with the needs of enterprises, we need to reform and innovate the traditional teaching methods. Specifically, we should strengthen the combination of theory and practice, adopt diversified teaching methods and means, update the content of teaching materials and strengthen the cooperation with enterprises, as well as provide students with more practical project experiences.

3. Introduction of the project teaching method

Facing an uncertain environment, the teaching methods of the courses are also in the process of exploration and continuous improvement. The teaching methods of PLC application talents' education should also keep up with the changes in the teaching environment. In the field of education, the choice of teaching methods is crucial to students' learning effect. After comparing the choice of various teaching methods, it is found that the project teaching method is particularly suitable for the teaching of electrical control and PLC applications.

The project teaching method is an efficient teaching method that emphasizes students' active participation and practical operation. It aims to improve students' practical skills, teamwork, and innovative thinking [8]. The project teaching method takes practical projects as the carrier. It enables students to explore, learn, and apply knowledge independently in the process of problem-solving. In the teaching of electrical control and PLC application, teachers can design a series of projects closely related to the course content. For example, designing a simple automation control system, realizing a PLC program for a specific function, and so on [9]. Students need to complete these projects independently or in groups. From the design and implementation of the project to the final evaluation, students are involved in the whole process to deeply understand the core knowledge of electrical control and PLC application. The most important feature of this teaching mode is its "active" and "practical" nature. Students are no longer passive recipients of knowledge, but take the initiative to analyze and solve problems [10]. They not only learned theoretical knowledge, but more importantly, developed practical operation and problem-solving skills in project implementation [11]. In addition, the project teaching method promotes the interaction and cooperation between teachers and students. Students can seek guidance from teachers when they encounter problems in project implementation, while teachers can provide personalized teaching support according to the actual situation of students. This interaction and cooperation not only enhances students' learning but also improves teachers' teaching quality [12]. The application of the project teaching method in teaching electrical control and PLC application is undoubtedly an innovative and effective attempt. It not only improves students' classroom participation and gives full play to students' subjective initiative, but also cultivates students' practical skills and innovative spirit. The project teaching method promotes communication between teachers and students, and students can better understand knowledge and master skills through communication with teachers. With the continuous development of education, the project teaching method will play a more important role in the teaching of electrical control and PLC.

4. Teaching practice of project teaching method applied to electrical control and PLC applications

In this paper, the project teaching method used in the PLC for the German BECKHOFF TwinCAT software, which is a PC-based motion control software; this software is divided into TwinCAT NC and TwinCAT PLC. TwinCAT NC is responsible for the direct control of the actual electrical hardware, such as solenoid valves or motors. TwinCAT PLC is used to write PLC programs [13-15]. In order to make the project approach more complete, our courses also incorporate the experience of how companies train engineers through projects to supplement the missing elements in the school classroom.

The first step is to define the project tasks. This part is to tell the students what they need to do in this class. According to the project requirements, the teacher assigns project tasks to the students. This project is a case of controlling a manipulator with three motors to pick up and feed materials. There are four tasks in this section: (1) Students analyze the electrical characteristics of the manipulator and the process of picking and feeding. (2) Through the analysis of this robot, students master the role of each electrical hardware and complete the

connection of the hardware circuit. (3) The teacher gives the control requirements of the project. Students write motion control programs according to the control requirements and complete the control of the manipulator. (4) Students summarize and analyze the project according to their degree of completion.

The second step is the stock of project knowledge. The teacher analyzes this project as a whole and compiles all the theoretical knowledge points needed for this project. These points are taught to the students before they carry out the project. (1) Hardware knowledge points: These include the definition of PLC's external I/O points, the principle and application of servo motors, the principle and application of servo drives, the principle and control of solenoid valves, the principle and application of relays, the principle and application of photoelectric sensors, the principle and application of AC contactors. (2) Software knowledge: Configuration of TwinCAT NC, use of TwinCAT PLC, and some PLC programming instructions required for this project. For instance, normally open contact instructions, normally closed contact instructions, output coil instructions, set instructions, reset instructions, rising edge instructions, falling edge instructions, take the inverse instruction and motor control require the MC_Power instruction and MC_MoveRelative instruction.

The third step is to analyze the control requirements and make a control plan. The teacher guides the students to analyze the control requirements of the project through the explanation of the project, modular decomposition of the project's control requirements, and draw a complete control flow chart. The program structure is designed so that the students can develop their own control plan.

In the fourth step, the students implement the developed project plan according to the project requirements. (1) Completing the allocation of PLC I/O points and the hardware construction of the project. (2) Configuring TwinCAT NC to control motors and solenoid valves, etc. through TwinCAT NC. At the same time, the students should test the performance of the motor and solenoid valve hardware. (3) Naming internal and external variables, naming motors, and assigning variable addresses before writing programs. (4) According to the control requirements and program architecture, writing the PLC control program in TwinCAT PLC. This includes the debugging program and the automatic program for the manipulator (5) Connecting TwinCAT NC with the program in TwinCAT PLC to complete the online simulation. Verifying the program and optimizing the program while simulating. (6) Controlling the manipulator with the written PLC program and performing debugging. After completion of debugging, applying the written automatic PLC program to control the manipulator. (7) Optimizing the control program and thinking about how to make the program shorter and still achieve the control requirements and optimizing the program.

During the students' projects, the teacher should pay attention to observing the students' progress and grasp the direction of the students' tasks. For example, if some students do not know how to use the motor's movement function MC_MoveRelative, the teacher needs to patiently guide the students to learn how to use the "Help" function in TwinCAT PLC. The teacher can find the documentation that explains the function block and learn the definition of each input and output of the function block, for students to understand what types of input and output variables are defined in MC_MoveRelative. This guided approach will allow students to seek solutions themselves when they encounter problems in the future.

In the fifth step, the students summarize the project. Students need to demonstrate the project to the teacher and give a PowerPoint presentation on the project.

The sixth step is checking and assessment by the teacher. The teacher checks and grades the students' projects. Finally, the teacher and students discuss the problems encountered in the project and the students' methods of solving the problems as well as their learning behaviors.

5. Conclusion

It has been proved that the use of the project teaching method in the teaching of electrical control and PLC applications is appropriate. The project teaching method focuses on practical operation and students are faced with an actual project. The project set by the teacher covers a variety of knowledge points that students need to learn. Students use their knowledge to solve the problems in the project to achieve the combination of theory and practice. It allows the application of the knowledge learned to the actual work, so that the students' practical skills are trained and they form a complete knowledge system.

Disclosure statement

The authors declare no conflict of interest.

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