Design of PLC Electrical Control System

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Abstract: *With the continuous expansion and development of factory enterprise scale, the development of automatic batching control system has also been accelerated. Batching mixing control system is a kind of raw materials mixed together according to a certain proportion, processing to produce a certain product process. This paper mainly designs and realizes the batching mixing control system of programmable logic controller (PLC). By precisely controlling the proportion of batching and the mixing time, the system is widely used in chemical, pharmaceutical, food and other fields to improve production efficiency and product quality. PLC system is a flexible, programmable electrical control equipment, because of its powerful, easy to use, high reliability characteristics, often used as the field data acquisition and equipment control. This paper mainly introduces the automatic control of liquid mixing system by Siemens PLC. The control object, hardware composition, software design and system function of the PLC based mixing, automatic mixing and automatic discharging system for two kinds of ingredients can simulate and display the whole working process of the liquid mixing system. The hardware of the system is mainly composed of S7-300 programmable controller, keys, stirring motor, frequency converter, solenoid valve and pump, etc. The programming software adopts Siemens programming software STEP7. The system transmits the collected field data to PLC through the weighing sensor, and after the PLC processes the field data logically, the corresponding control command is issued to complete the automatic control of the system. Finally, the system uses the communication interface to connect with the host computer to realize the communication between PLC and computer. The system has high degree of automation, strong flexibility, and can meet different production process requirements.*

Keywords: PLC; Automation; Mixing control system.

1. INTRODUCTION

1.1 Background to the selection of the topic

In modern industrial production, precise batching and mixing processes are essential to ensure product quality and improve production efficiency. In order to meet the demand for precise control of the production process, programmable logic controller (PLC) automated batching and mixing control system has gradually become a key technology in the industry. Nowadays, with the continuous improvement of market requirements for product quality, industrial production of raw materials in the accurate dosage and mixing process control has become particularly important, the traditional manual dosage and mixing mode of operation may involve corrosive, flammable and explosive, toxic and other hazardous materials, increasing the operator's safety risks, but also exists in the low production efficiency, error-prone and other issues. The introduction of PLC automation control system can realise the automation of batching and mixing process, which not only improves the production efficiency and reduces the influence of human operation on product quality but also greatly ensures the safety of the staff. Through its highly programmable and real-time control characteristics, it can effectively improve the accuracy and consistency of the batching and mixing process.PLC system has real-time data acquisition and recording functions, which can monitor and record the parameters of the batching and mixing process. This provides reliable data support for continuous improvement and quality control of the production process. Nowadays, most factory production processes need to be integrated as a whole, sometimes different products may require different formulas and mixing parameters, and traditional mixing control systems are often difficult to achieve effective information interaction with other production equipment.PLC systems have a natural advantage in the realization of the integration of the various aspects of the system, coupled with the flexibility of the system can easily adapt to the needs of a variety of production requirements, and through a simple modification of the program to achieve the production of different products. production through simple programme modification. Together with the continuous maturity of PLC technology and the gradual decline in price, its application in industrial automation is becoming more and more widespread.

PLC-based mixing control systems have solved some of the problems of conventional systems by optimising for increased automation, accuracy, safety and productivity. These improvements help to improve production quality, reduce costs, and meet the requirements of modern plants for intelligent production. Today's PLC automatic control mixing systems account for an increasing proportion of the market and are widely used in oil refining and petroleum, chemical, food, pharmaceutical, construction, metallurgy, papermaking, environmental protection, building materials, ceramics, paints, coatings and other industries.

1.2 Purpose and significance of the selection

This course is designed to study the applications and advantages of PLC-based automated batching and mixing control systems, and to learn how to use the PLC programming language to write control logic for precise control of automated batching and mixing processes. To understand the basic principles of PLC, connection and configuration of input/output (I/O) modules, and how to write and debug PLC programmes. Learn how to optimise the mixing process to improve product quality and productivity. Understand the system architecture, communication protocols and data acquisition methods for real-time monitoring and control of the batching and mixing process. Acquire, record and analyse the parameters and data of the batching and mixing process in real time through the PLC system. Understand data acquisition methods, data storage and transmission techniques, and how to use this data for process analysis, quality control and continuous improvement.

PLC dosage control systems play a great role in improving production efficiency and product quality, as well as optimising dosage accuracy and consistency and improving the flexibility and adjustability of the production process, which enables the system to be used in more factories and gain more market share. Nowadays industrial intelligence and intelligent manufacturing are becoming more and more common, and PLC automation control system as an important part of industrial intelligence and intelligent manufacturing. In-depth study of PLC-based automated batching and mixing control system, to explore its applications and advantages, to provide advanced technical support for the batching and mixing process in industrial production, and to promote the improvement of production efficiency, product quality and industrial intelligent development.

1.3 Current status and development trend of domestic and overseas research

1.3.1 Current status of domestic research

With the development of modern computer and microelectronics technology, its development has experienced several stages of manual control, mechanical and electrical control, microcontroller control, industrial control computer centralised control, PLC control. China's PLC technology compared to foreign countries started late in the 1980s only began to develop, but with the continuous development of science and technology and industrial automation needs increase, PLC's function has also had a great improvement in the expansion of the scope of control, the composition of the module is also gradually increasing; the current PLC newly added many applications of the module, such as temperature, motion and PID control module, etc.; programmable controllers Programmable controllers are universal and open to each other; the constant refreshment of computing speed is also getting faster and faster; the function of networking among each other is further enhanced. In China, the research of automated batching and mixing control system for different industries is widely carried out. For example, the batching and mixing process of food, chemical, pharmaceutical, building materials and other industries are all concerned. Current research focuses on the optimisation of control algorithms and system integration to improve the accuracy and stability of the batching and mixing process. Researchers are committed to developing advanced control strategies and algorithms so that the system can automatically adapt to different production demands and process parameters. Data acquisition and analysis technology is also the focus of domestic research. By collecting and analysing the parameters and data during the batching and mixing process, it is possible to gain an in-depth understanding of the characteristics of the mixing process and provide support for quality control and production optimisation. Attention has also been paid to the safety and reliability of the system, which requires consideration of stable operation in harsh environments and contingency measures to cope with failures and abnormalities.

1.3.2 Current status of foreign research

In 1969, the U.S. DEC successfully developed the world's first PLC. 1971, programmable controllers have been used in metallurgy, paper and other fields. 1975-1976, the U.S., Germany will be the CPU controller applied to the PLC, memory and erase the memory of switching integrated circuits, combined with technology, electrical control of the single-chip technology to achieve a large-scale processor processor programmable controller. Integration, can be applied to industrial environments, with a more reliable, more powerful functions, more flexible, so that the PLC stepped into the process of practical use. At present, this technology is gradually developing in the direction of intelligence, modernisation and diversification, and has become one of the key technologies in the field of industrial automation.

In foreign research, the automatic control mixing system tends to develop in the direction of more intelligent and networked. Researchers are committed to integrating PLC systems with other intelligent devices and Internet of Things technologies to achieve real-time monitoring, remote control and data sharing to improve productivity and responsiveness. Foreign research is increasingly focusing on the application of big data and artificial intelligence in automatic control mixing systems. Through techniques such as data analytics, machine learning and deep learning, researchers try to achieve intelligent optimisation, predictive maintenance and fault diagnosis of the production process. Overall, foreign research focuses on integrating advanced technologies to make automatically controlled mixing systems smarter, more efficient, and more sustainable. These trends provide a new direction for the development of the industrial automation field and bring more possibilities for future research and practice.

1.3.3 Development trends

Nowadays PLC-based automatic control mixing system plays an important role in industrial production, with the continuous development of PLC technology, PLC-based automatic control mixing system also has a better development direction. Here are a few of the more popular development direction.

Intelligent and internet of Things: with the development of the Internet of Things, automatic control mixing system tends to be intelligent. By integrating the PLC system with other intelligent devices, sensors and data communication technology to achieve automation, real-time monitoring and remote control, improve production efficiency and flexibility of the production process.

Integration of Big Data and Artificial Intelligence Technology: The application of Big Data and Artificial Intelligence technology will bring more possibilities to the automatic control mixing system. Through the use of data acquisition, analysis and prediction technologies, the system can achieve intelligent adaptive regulation and fault diagnosis, and provide data-based optimisation recommendations to provide higher reliability and efficiency for the production process.

Advanced control algorithms and optimisation methods: Control algorithms and optimisation methods for automatic control mixing systems will continue to improve and evolve. Advanced technologies such as fuzzy control, neural networks and model predictive control are used to improve mixing effectiveness, reduce energy consumption and optimise resource utilisation.

Improvement of human-computer interaction interface: Improvement of the user interface will enable the operator to monitor and control the automatic control mixing system more conveniently and intuitively. A more friendly and easy-to-use interface design will help the operator to grasp the system status in real time, adjust parameters and deal with abnormal situations.

Sustainable development and energy efficiency: with the growing concern for environmental sustainability and energy efficiency, automatic control of mixing systems will be more focused on reducing energy consumption and waste generation. The research will aim to optimise the batching and mixing process, reduce resource wastage, improve productivity and find innovative solutions for alternative energy and green processes.

Overall, PLC-based automatic control mixing systems will continue to develop in the direction of intelligence, networking and sustainability. This will provide more efficient, accurate and reliable batching and mixing process control for industrial production and promote the rapid development of industrial production.

1.4 Main elements

This course design focuses on the functional control of mixing using Siemens S7-300 series PLC.

The main elements include the following:

Software: according to the requirements of the design, module decomposition of the system, analyse the system module by module, master the module system on the basis of the overall system research and analysis, write the required control program to achieve the function of dosage mixing. Draw the PLC sequence function block diagram, ladder diagram, timing diagram;

Hardware: through the functional analysis of batching and mixing, understand the working principle of batching and mixing, and analyse the hardware structure. Draw the main wiring diagram of PLC, I/O allocation table, PLC wiring diagram;

Program the ladder diagram of the corresponding function on the simulation software through the programming software STEP7-Micro_WIN SP9.

1.5 Design Thinking

The difficulty in designing this course is to first figure out how the object mixing system works and in doing so. Consider whether it meets the expected requirements. Meanwhile, to complete this project design, we are divided into the following steps to achieve:

(1) Establish the design and understand how it works;

(2) Device selection;

(3) Hardware design and software design;

(4) Carry out simulation debugging;

(5) Actual commissioning at the laboratory site.

2. OVERALL PROGRAMME

2.1 Subject Needs

This course design studies a PLC controlled dosing and mixing system with design requirements:

(1) Able to transport ingredients from batching tank to mixing tank;

(2) The feeding of each ingredient can be controlled separately;

(3) Able to control the mixing speed of the mixing system;

(4) Real-time control of the mixing process through human-machine interactive interface;

(5) Able to configure the automatic mixing formula.

2.2 Design Objectives

Through this course design, you can gain an in-depth understanding of the design process of the electrical control system, design requirements, the content of the work that should be completed and specific design methods. Specifically, the following abilities can be developed:

(1) Ability to work independently and creatively;

(2) The ability to apply professional and basic knowledge in an integrated manner;

(3) Ability to solve practical engineering problems;

(4) Ability to consult library materials, product manuals and various tools;

(5) Ability to write technical reports and prepare technical information.

2.3 Needs analysis

In the subject requirement, the automatic mixing function of the dosage mixing system needs to be completed. To achieve the above function, PLC is used and it is done through ladder diagram. Meanwhile, the realisation scheme should include hardware scheme and software scheme. The hardware scheme needs to select PLC controller and related low-voltage electrical appliances, and complete the electrical control schematic diagram, I/O allocation of PLC, and wiring diagram of PLC. The software solution needs to draw timing diagrams, sequential function block diagrams, and write ladder diagrams to complete the logic control of the three motors, and perform simulation and demonstration verification.

2.4 Technical programmes

PLC control system is widely used in various industrial control systems because of its small size, powerful function, high reliability and large flexibility and expandability. Adopting PLC to control the batching and mixing system can not only realise the automatic mixing of batching, but also optimize the response state of the mixing system and improve the reliability and safety of the system.

Small batching and mixing system consists of three subsystems: material transport subsystem, mixing subsystem and man-machine subsystem, and the functions of material transport, mixing and real-time control are realised by connecting the control subsystem with PLC as the control system. The overall system block diagram of small batching and mixing control system is shown in Figure 2-1.
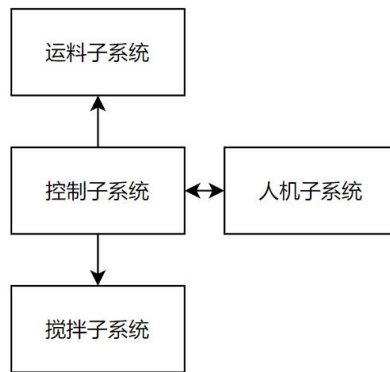
Figure 2-1: Block diagram of the overall system

The main function of the material transport sub-system is to check and control the liquid level, as well as the control of pumps, delivery of ingredients and so on. Using load cell, screw encoder, liquid level switch, etc. to batching for liquid weight and upper and lower water level alarm detection, and will collect the signal output to the controller, by the controller to analyse and process and use, transport sub-system structure diagram shown in Figure 2-2.
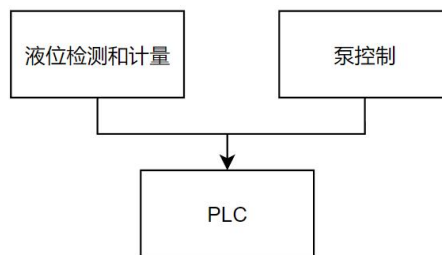
Figure 2-2: Structure of the material transport subsystem

The main function of the mixing sub-system is to control the mixing motor, control the forward and reverse rotation of the mixing motor, mixing speed and time, and also need to detect and control the liquid level, the PLC through the bus to the frequency converter for speed control and control of the mixing motor, the mixing sub-system structure diagram shown in Figure 2-3.
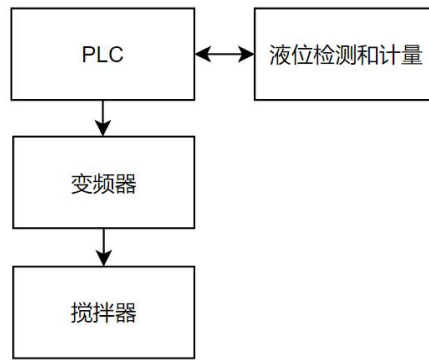
Figure 2-3: Stirring Subsystem Structure

The main function of the man-machine sub-system is the selection of manual/automatic operation, parameter setting, recipe setting and other operations, and it plays a role in setting parameters for the whole mixing system, and the structure diagram of the man-machine sub-system is shown in Figure 2-4.
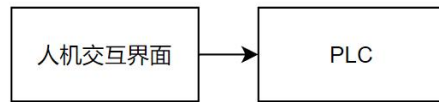

Figure 2-4: Man-machine subsystem structure diagram

The main parts of the system include PLC, liquid level detection device, CPU, motor, field control cabinet and alarm device. Liquid level transmitter through the site of the height of the liquid level of the collection, and will be converted into a current signal to the PLC centre analysis, PLC based on the site conditions and external input signals to control the mixer system, and the signal will be transmitted to the computer centre for processing, and then finally display the operating instructions, such as operating errors and alarm, the overall framework of the system as shown in Figure 2-5.

Figure 2-5: Overall System Framework Diagram

2.5 Programme validation

Functional demonstration: use STEP7 programming software, ladder design based on S7-300 to complete the basic functions of the dosage mixing system, and then use S7-PLCSIM to simulate and analyse the ladder diagram.

Technical justification: nowadays the development of batching and mixing technology has been mature, this design is more basic batching and mixing function design, the feasibility of the technical programme is high.

3. HARDWARE DESIGN

3.1 Hardware system block diagram

The modules that constitute the small batching and mixing system are material transport module, mixing module, human-computer interface, control system, etc. The material transport module is mainly composed of load cell, inlet and outlet pumps; the mixing module is mainly composed of frequency converter and mixing motor; the human-computer interface is mainly composed of touch screen, switch and indicator; the control system is controlled by PLC, and the block diagram of the hardware of the small batching and mixing control system is shown in Figure 3-1 shows.
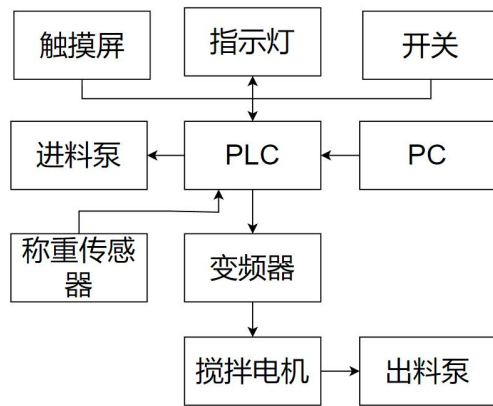
Figure 3-1: Hardware System Block Diagram

3.2 System layout

3.2.1 Small reactors and feedstock tanks

Adopting thickened acrylic transparent tank as raw material storage tank, located in the upper part of the device, equipped with load cell and stirring motor, stirring paddle, used for feeding reaction, dosage control and speed, temperature control (optional), you can visually observe the entire mixing process.
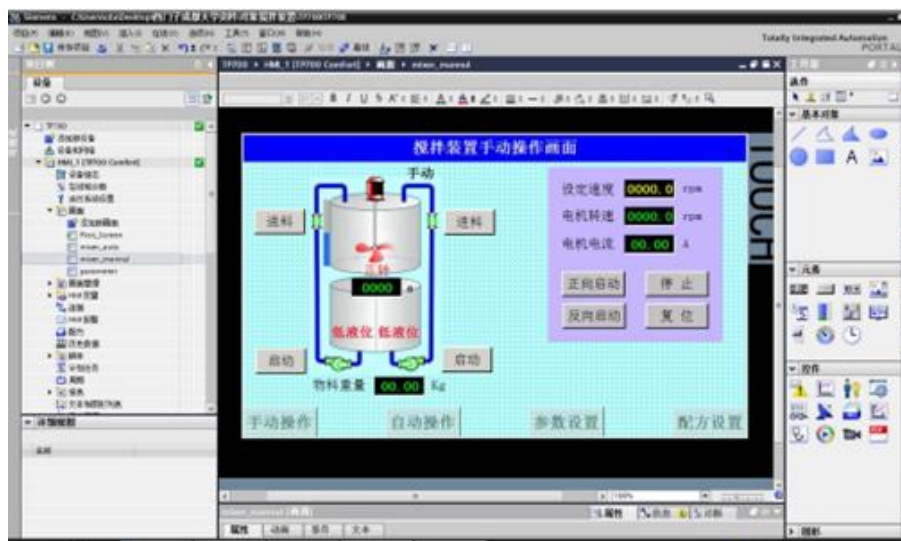
Figure 3-2: Small reactor and raw material storage tanks

Figure 3-3: Parameter Setting Interface Diagram

3.2.2 Instrument settings

Set the weight of the dosed liquid, forward and reverse rotation time, rotational speed, and output the collected signal to the controller, which will be analysed and processed and used by the controller.

Figure 3-4: Parameter Setting Interface

Figure 3-5: Recipe Setting Interface

3.3 Electrical Selection

Low-voltage appliances in the low-voltage power supply and distribution system, electric power traction system and automatic control system plays an extremely important role, is the basis of electrical control technology, the performance of the low-voltage appliances used in the performance of the control system is directly related to the performance of the system has a direct relationship between the reliability of the system, the advancement of the system and the economy. The low-voltage appliances are of various types, with different structural forms and different functions of the working principle machine, therefore, it is necessary to select low-voltage appliances at the time of design.

The main low-voltage appliances to be used for this hardware design are: inverters and push buttons. When selecting the type, the type is selected according to the use of low-voltage electrical appliances. According to JB/T2930-2007 low-voltage electrical product modeling method provides that the general model of low-voltage electrical components of the type shown in Figure 3-6.
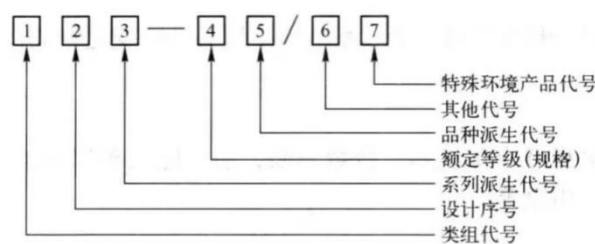
Figure 3-6: Common types of low voltage appliances

1 - Class group designator: With two or three hanyu pinyin letters, the first for the category code, the second and third for the group code, on behalf of the product name, and model registration department to determine.

2 - Design serial number: It is represented by an Arabic numeral with an unlimited number of digits, which is standardised by the type registration authority.

3 - Series Derivation No.: Generally by one or two Hanyu Pinyin letters to indicate the characteristics of the full range of product changes, the model registration department to determine the unified.

4 - Rated class: Expressed in Arabic numerals, the number of bits is not limited, according to the main parameters of each product to determine, generally expressed in current, voltage or capacity parameters.

5 - Variety-derived codes: Generally use one or two Chinese pinyin letters to indicate the change characteristics of individual varieties within the series, the model registration department to determine the unified.

6 - Other codes: Expressed in Arabic numerals or Hanyu Pinyin letters, the number of bits is not limited, indicating that in addition to the variety of product features that require further explanation, such as the number of poles, release mode, use, etc..

7 - Special environment code: Indicates the environmental adaptability characteristics of the product, which are uniformly determined by the type registration authority.

3.3.1 Frequency converters

(1) Definition and working principle

An inverter is a power conversion device that adjusts the power frequency to a desired value to control the speed of a motor. It is mainly composed of three parts: rectifier, levelling circuit and inverter. By changing the voltage and frequency of the output power supply, the frequency converter can accurately control the speed of the motor and achieve the purpose of energy saving and speed regulation.

The operating principle of the inverter is based on the synchronous speed formula of an AC motor $N=60f/p$, where N is the synchronous speed of the motor, f is the power supply frequency, and P is the number of motor pole pairs. The frequency converter can control the motor speed N by changing the power frequency f.

(2) Types

① Siemens G120

Parameters: Rated voltage is 380 ~ 480 VAC, rated power is 1.5 KW.

Functional index: With vector control, V/F control, slip compensation, torque compensation and so on.

Application places: It is suitable for a variety of industrial applications, including automotive, textile, printing, chemical and so on. It can be widely used in various industrial production lines, such as mixing equipment, conveyor belts, hydraulic pumps, etc., as well as automation equipment, such as robots and machine tools.

Performance indicators: Control accuracy, response speed, output torque and other performance, but also has a strong overload capacity, good heat dissipation performance, reliability and other advantages.

Price: Ranges from about $1000-$5000.

Figure 3-7: Siemens G120

② Schneider's AT630

Parameters: Rated voltage is 240VAC, rated power is 22KW.

Functional index: With vector control, V/F control, slip compensation, torque compensation and so on.

Application places: Suitable for a variety of industrial applications, including petroleum, chemical, electric power, metallurgy and so on. It can be widely used in various industrial production lines, such as pumps, fans, compressors, etc., as well as automated equipment, such as large machine tools and winches.

Performance indicators: Control accuracy, response speed, output torque and other performance, but also has a strong overload capacity, good heat dissipation performance, reliability and other advantages.

Price: Ranges from about $4,000-$8,000.

Figure 3-8: Schneider's AT630

(3) Requirements of batching and mixing system on frequency converter

The batching and mixing system has high requirements on the frequency converter, which needs to have high stability and accuracy, as well as good compatibility and safety. At the same time, its rated voltage and power should meet the rated voltage and power of the batching and mixing system.

(4) Selection

According to 2, 3 comprehensive consideration, choose Siemens (Siemens) G120 as the frequency converter of this design.

3.2.2 Switch buttons

(1) Definition and working principle

Pushbutton is a simple structure, the use of a wide range of manual electrical appliances, it is in the control circuit by manually issuing control signals to control relays, contactors or interlock circuits, etc., rather than directly controlling the main circuit of the on and off, the general allowable current through the button contacts does not exceed 5A.

① PBS-11B

Parameters: Rated current 3A,Rated voltage 250VAC.

Functional indicators: Single-pole, disconnect normally closed, instantaneous action.

Price: $2 or so.

Figure 3-9: PBS-11B

② PBS-15B

Parameters: Rated current 5A,Rated voltage 250VAC.

Functional indicators: Single-pole, disconnect normally closed, instantaneous action.

Price: $3 or so.

Figure 3-10: PBS-15B

(2) Requirements for buttons of dosage mixing system

The most suitable buttons for automatic washing machines should be single-pole, disconnect normally closed, instantaneous action, rated current and voltage in accordance with the rating of the washing machine motor, suitable size for mounting on the control board of the washing machine, have reliable performance, and be reasonably priced.

(3) Selection

Considering 2 and 3 together, you should choose PBS-11B, both of them have the same function and close performance, but PBS-11B is cheaper and can reduce cost.

3.4 PLC Selection

Due to the wide variety of PLC products, different models, there are different structural forms, performance, capacity, command system, programming methods, etc., therefore, the reasonable selection of PLC, for improving the technology of PLC control system has an extremely important significance.

The basic principle of model selection is to meet the requirements of the control function under the premise of ensuring that the system works reliably, easy to maintain and use and the best performance-price ratio. Specific factors to be considered are: reasonable structure; function, scale is comparable; model unity. Detailed selection of objects are: manufacturers and models, input and output points, control functions.

3.4.1 PLC manufacturer and model

To determine the PLC manufacturer, the main considerations are the designer's familiarity with PLCs from different manufacturers, the consistency of supporting products and technical services, etc. As for the reliability of

the PLC, in principle, there should not be any problem of poor reliability of the products of large companies. And this semester we mainly study the knowledge of Siemens S7-300 PLC, therefore, we choose Siemens S7-300 PLC as the PLC of this course design.

3.4.2 Power Module

The power supply module of S7-300 PLC is to convert the power supply voltage to DC24V operating voltage to provide reliable power supply for CPU and peripheral control circuits and even loads.The power supply module of S7-300 PLC has four models, which are PS 305 (2A), PS 307 (2A), PS 307 (5A) and PS 307 (10A). According to the design requirements, PS 307 (5A) is selected as the power supply module for this course design.

3.4.3 CPU module

The S7-300 PLC has many different models of CPUs, and different models have different technical specifications and performance parameters. Each CPU corresponds to a model number, and the meaning of the model number is shown in Figure 3-19, where:

(1) Bit 31x indicates the CPU serial number, which is progressively more functional from low to high;

(2) The bit indicates the CPU type, which is not available for the standard type, the compact type is indicated by C, the technical function type is indicated by T, and the fail-safe type is indicated by F;

(3) Bit indicates the number of communication interfaces the CPU has;

(4) Bit indicates the type of communication interface, DP indicates PROFIBUS DP interface, PN indicates PROFINET interface, and PtP indicates point-to-point interface.
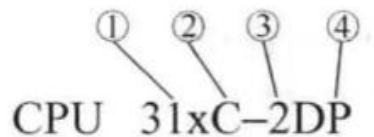
Figure 3-11: CPU Model Schematic

Based on the amount of programmes designed, networking and other requirements, CPU 315-2DP was selected as the CPU module for this course design.

3.4.4 Input/output modules

There are four types of input/output modules: digital, analogue, Ex and F. The digital input/output module has the functions of both digital input module and digital output module, and the rated voltages of both inputs/outputs are DC 24V; therefore, the digital input/output module is selected.

There are two kinds of digital inputs/outputs, SM323 and SM327, of which SM323 has two kinds of inputs and outputs, 8 points and 16 points; SM327 has 8 digital inputs and 8 independently programmable inputs/outputs. Therefore, according to the actual design requirements, the SM323 input and output points are selected as 8-point input/output module.

3.5 Input-output allocation table

Table 3-1: Input-Output Distribution Table

Importation			Exports		
Notation	Address	Clarification	Notation	Address	Clarification
SB0	I0.0	Emergency stop button	KM1	Q0.0	Material A pump
SB1	I0.1	Tank A level switch	KM2	Q0.1	Material B pump
SB2	I0.2	Tank B level switch	TA	Q0.2	Solenoid A
SB3	I0.3	Remote Toggle Switch	TB	Q0.3	Solenoid B
QS	PIW268	Weighing sensors			

3.5.1 Enter a description of the function:

Emergency stop button control circuit emergency stop, in the electrical control circuit diagram of its electrical symbol for SB0, the corresponding PLC input address for I0.0;

Tank A level switch controls the level of tank A. In the electrical control circuit diagram, its electrical symbol is SB1, and the corresponding PLC input address is I0.1.

Tank B level switch controls the level of tank B. In the electrical control circuit diagram, its electrical symbol is SB2, and the corresponding PLC input address is I0.2.

Remote toggle switch to achieve remote control, in the electrical control circuit diagram of its electrical symbol for SB3, the corresponding PLC input address is I0.3;.

The load cell implements the liquid weight detection and its electrical symbol is QS in the electrical control circuit diagram, and the corresponding PLC input address is PIW268.

3.5.2 Output function description:

A material pump indicates the inlet and outlet of A material in the small batching and mixing system, its electrical symbol is KM1 in the electrical control circuit diagram, and the corresponding PLC output address is Q 0.0.

B material pump indicates the inlet and outlet of B material in the small batching and mixing system, its electrical symbol is KM2 in the electrical control circuit diagram, and the corresponding PLC output address is Q 0.1.

Solenoid valve A controls the inlet and outlet of material A in a small batching and mixing system, whose electrical symbol is TA in the electrical control circuit diagram, and whose corresponding PLC output address is Q 0.3.

Solenoid valve B controls the entry and exit of material B in the small batching and mixing system, and its electrical symbol is TB in the electrical control circuit diagram, and the corresponding PLC output address is Q 0.4.

3.6 PLC Wiring Diagram
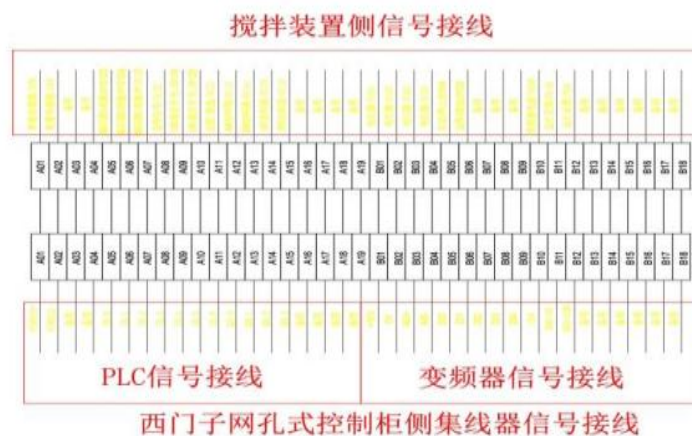
Figure 3-12: PLC Wiring Diagram

4. SOFTWARE DESIGN

4.1 Functional Block Diagram

The whole system is controlled by PLC, which transfers the input signals to PLC, which then realises the control of motor and display module according to the received signals, and also needs to connect the power module to realise

the power supply function. The functional block diagram of the small batching and mixing system is shown in Figure 4-1.
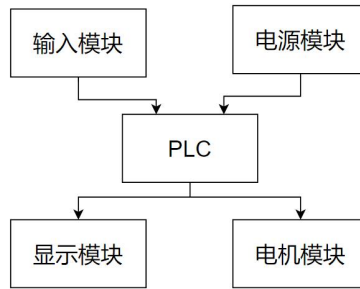
Figure 4-1: System Function Block Diagram

4.2 Flowchart
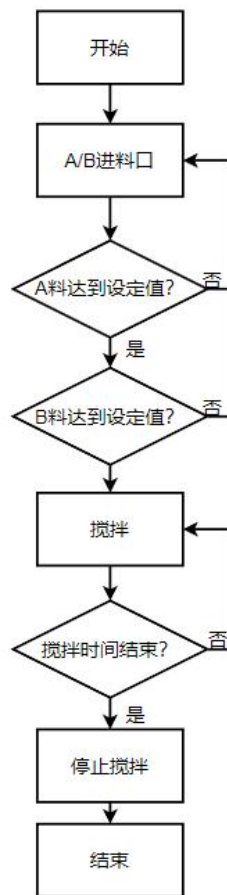
Figure 4-2: System Flowchart

When the small batching and mixing system starts to run, A/B material will be fed according to the proportion set in the formula, and after reaching the preset value respectively, the system will start to mix, and if it does not reach the preset value, it will continue to add more material, and when the mixing time is over, the mixing will be stopped, and at the same time, it will exit the mixing programme.

4.3 Table of symbols

Figure 4-3: Symbol Table 1

Figure 4-2: Symbol Table 2

4.4 Ladder diagrams

The ladder diagram is written using Siemens STEP7/MICROWIN software, and the ladder diagram is written as follows Figure 4-3 shows.
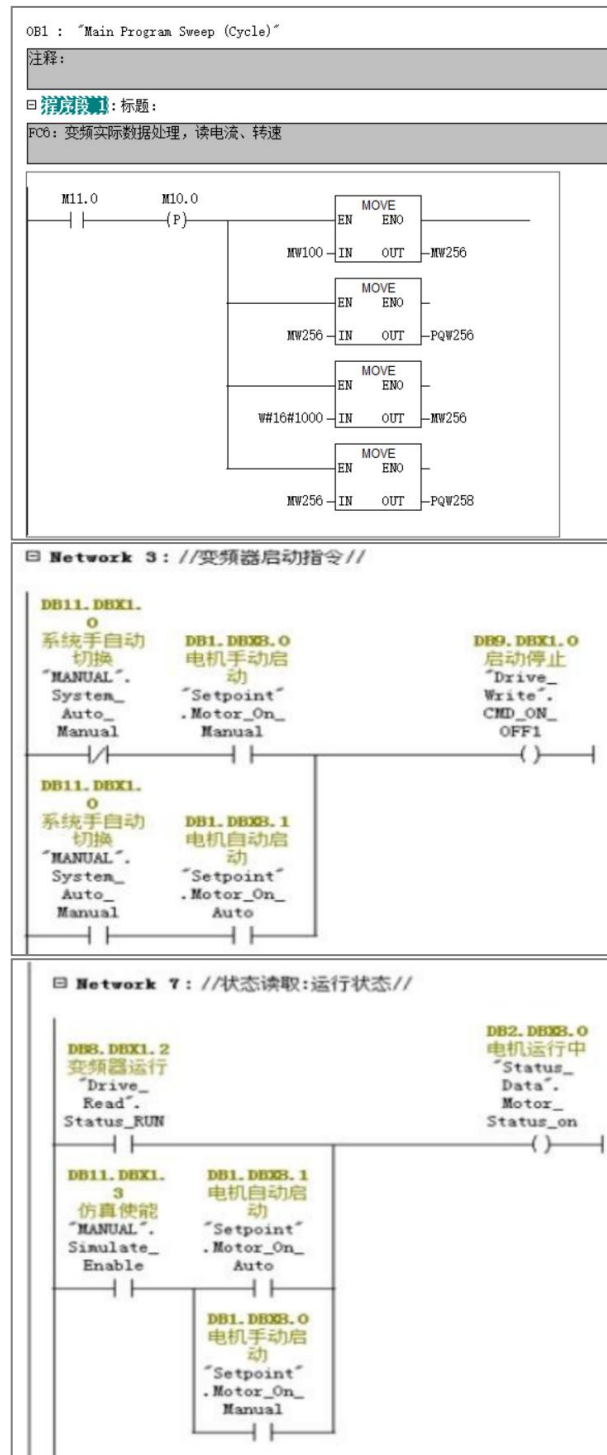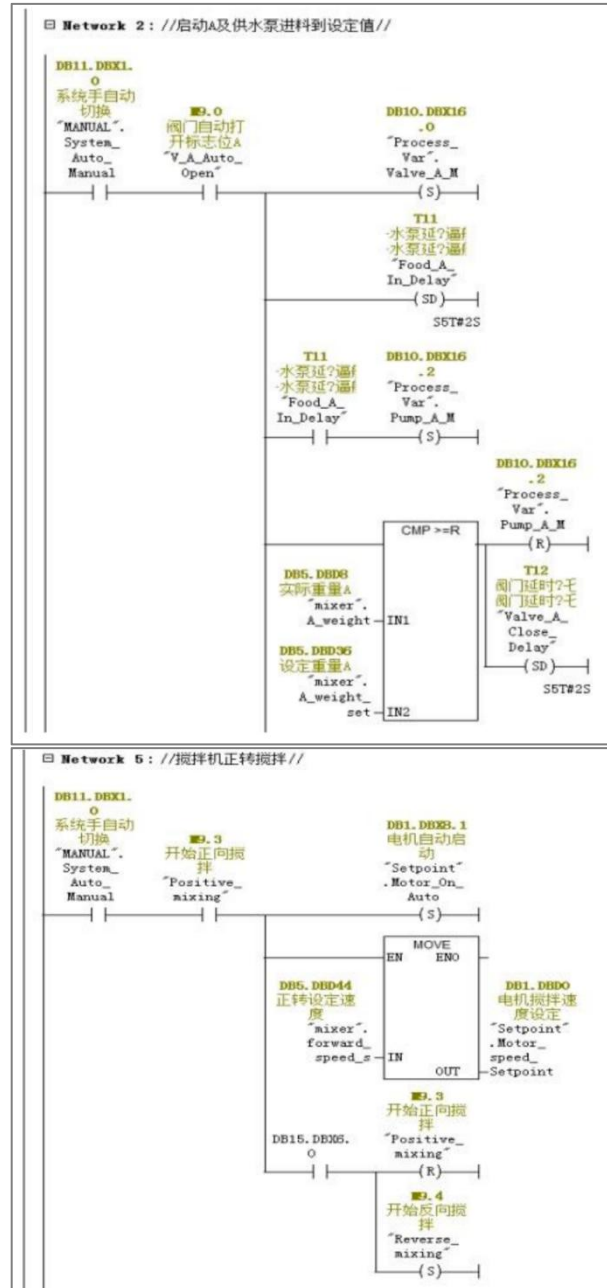
Figure 4-3: Ladder Diagram

4.5 Human-computer interaction interface design

The HMI is mainly used for the operation of the mixing unit, which allows manual and automatic switching, recipe setting, motor control, as well as stop and start operations on the control panel.

To set up the HMI, proceed as follows:

(1) Create a new project;

(2) Select the appropriate touch screen model;

(3) Open the project view and enter the screen editor;
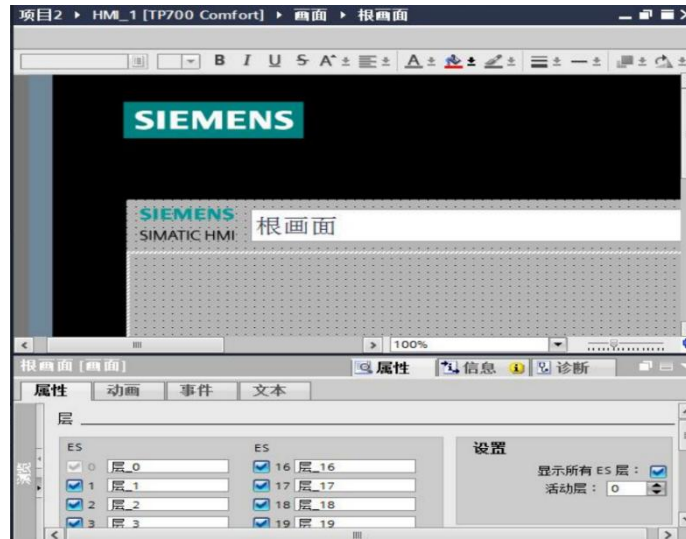
Figure 4-4: Screen Edit Interface

(4) According to the process in Step7 write control programme, through the touch screen control inverter operation;

(5) Prepare data block DB11 (MANUA);

Figure 4-5: Data Block DB11

(6) Write the programme FC8 (Common logic);

(7) Build HMI variables in TIA Portal to exchange data with PLC;

(8) Add a new screen named mixer_mannul as shown in the figure below, refer to the case of the programme to place a number of buttons and I/O domains, in the event of button presses to add the appropriate function to set the relevant command bit, in the I/O domains connected to the need to display the actual value. After configuring the touch screen program, download the configuration to the touch screen, combined with the written program, test the corresponding functions properly, and its human-machine interface as shown in Figure 4-6.
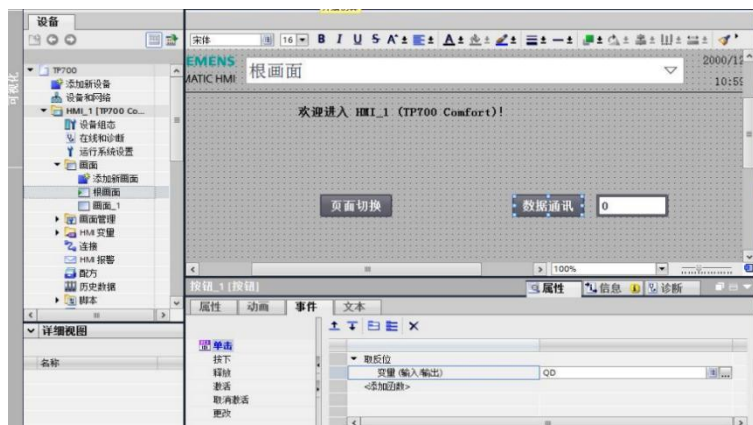

Figure 4-6: Man-machine operation interface diagram

5.   TESTING AND VALIDATION

5.1 Setting up the environment

To verify the correctness of the design, editing, compilation, simulation and testing environments need to be set up.

5.1.1 Setting up the editorial compilation environment

(1) Installation of software

① Installation of STEP7 software

Locate the Setup.exe file in the STEP7 MicroWINV55 or STEP7 MicroWINV56 software directory and run Setup.exe to start the installation. The installation wizard will guide you through the installation process. After the installation is complete, a shortcut "SIMATIC MANAGER" will be created on the desktop. If you are reminded to restart your computer during the installation, exit the installation, type "regedit" at the command prompt in WINDOWS,   and   find   and   delete   the   following   registry   entries: [HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\   control\Session   Manager]   under [HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Session Manager], and delete the following registry entries. control\Session Manager] under "PendingFileRenameOperation", and then re-run Setup.exe for installation.

② Installation of S7_PLCSIM simulation software

PLCSIM is a very powerful simulation software provided by Siemens, it is integrated with STEP7 programming software, the computer does not need to be connected to any PLC hardware during simulation, it is used to simulate the function of S7-300 CPU on computer, it can find and queue up the errors in the development stage, so as to improve the quality of the user's programme, reduce the testing cost and increase the working efficiency. In the S7-PLCSIM V5.4 SP5 directory, find the Setup.exe file and run Setup.exe to start the installation. Follow the prompts to complete the installation. After the installation is completed, it is automatically integrated into "SIMATIC MANAGER".

A screenshot of the desktop after successful software installation is shown in Figure 5-1.

Figure 5-1: Software Icons

(2) Establishment of the compilation and programming environment

① Establishment of the project

Double-click the shortcut "SIMATIC MANAGER" icon on the desktop to start the programme.

Click Command from the menu, follow the prompts to create a new project, the project name can be commanded as "kcsj", as shown in Figure 5-2.
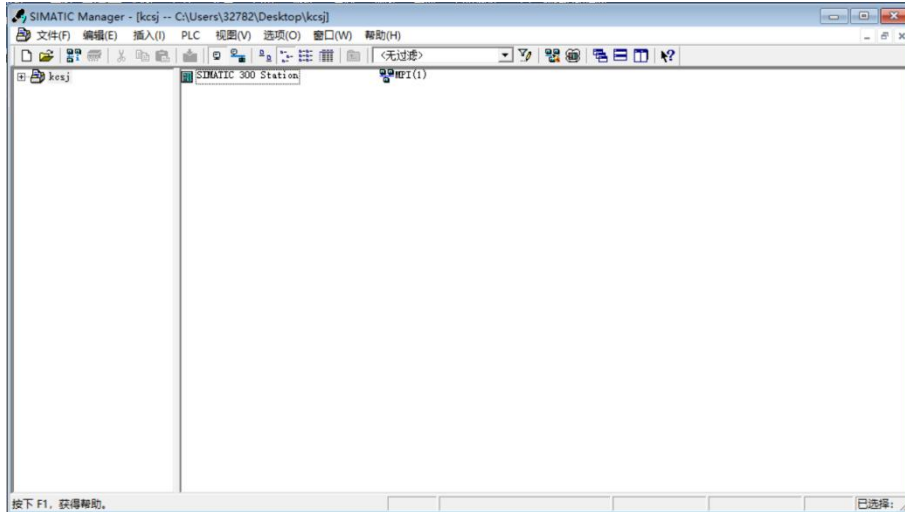
Figure 5-2: Screenshot of New Project Interface

② Entering the compilation environment

Insert the S7-300 station in the project window by right clicking on the mouse. Right click on the project window and select "SIMATIC 300 Station" under "Insert New Object" to insert the S7-300 station.

Click the inserted "SIMATIC 300 Station" and double click "hardware" in the right window. Click the inserted "SIMATIC 300 Station", double click "hardware" in the right window to enter the hardware configuration window, configure the hardware according to the following parameters, and then save and exit. The parameters are as follows, and the interface of hardware configuration is shown in Figure 5-3:

1) Insert a rail "rack"

2) Slot 1 Insert Power Supply Module PS307 5A

3) Slot 2 insert CPU 315-5DP
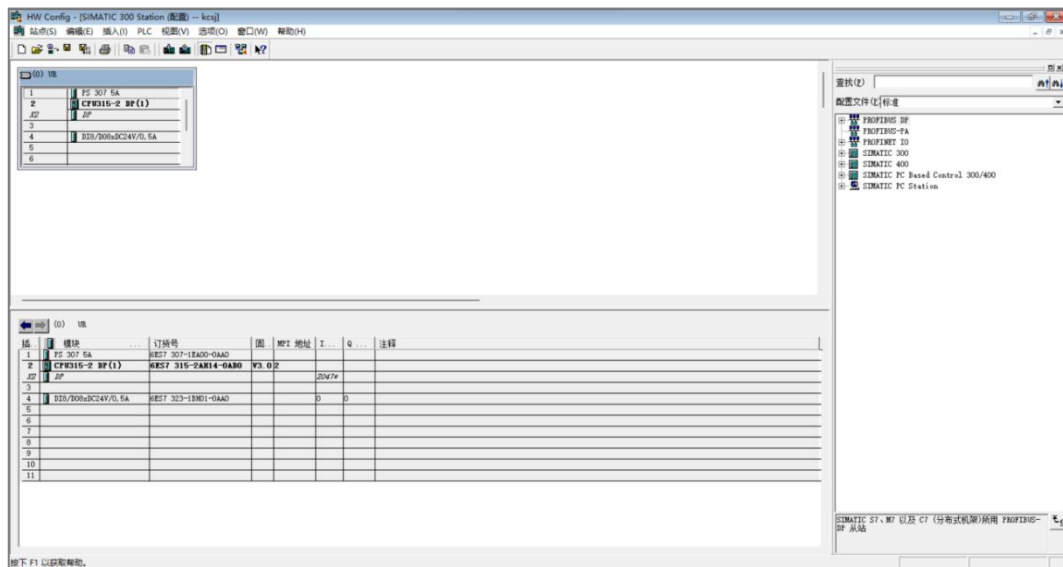
4) Slot 4 Insert SM323 DI8/DO8*24VDC/0.5A

Figure 5-3: Hardware Configuration Interface Screenshot

③ Enter the project management interface, select S7 Program (1) under CPU 51-2 DP, double click "Symbols" on the right side to input global symbol variables, the screenshot of Symbol Table interface is shown in Figure 5-4.
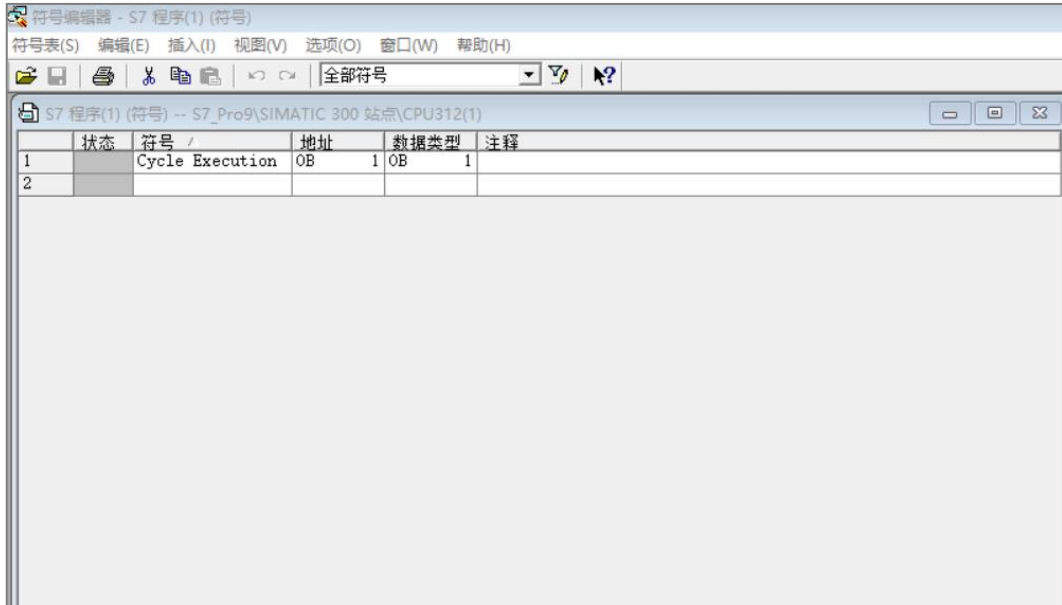

Figure 5-4: Screenshot of Symbol Table Interface

④ Double-click the right side of the "Blocks" to enter the programme writing interface, the sequence of function block diagrams written as a ladder diagram, input to OB1, save the programme after completion, STEP-7 programme editing and compilation interface screenshot shown in Figure 5-5.
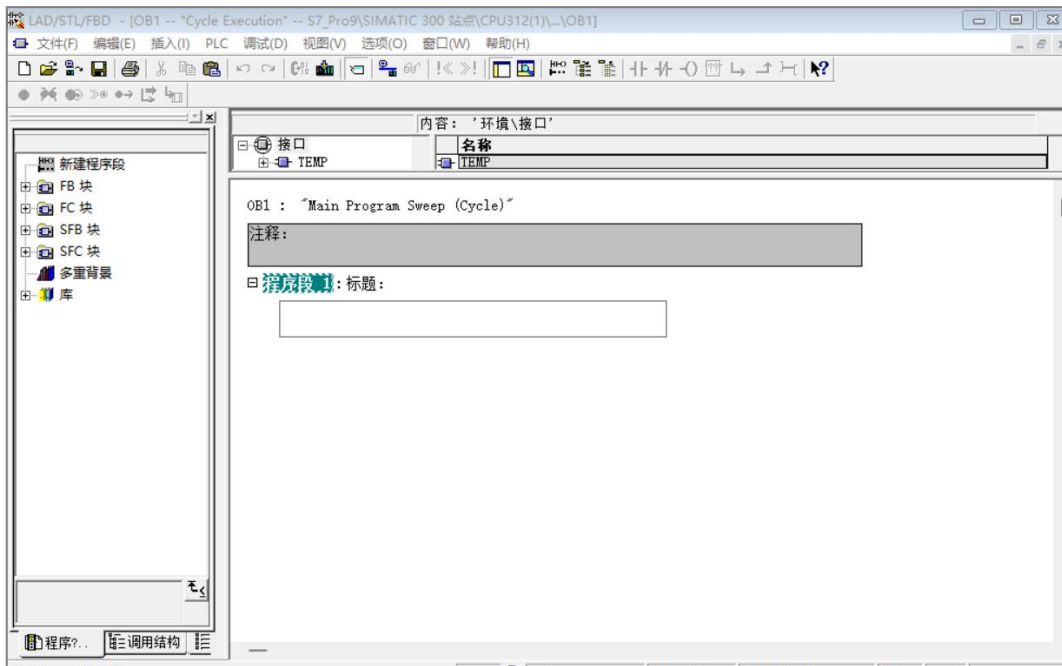

Figure 5- 5: STEP-7 programme editing and compilation interface

5.1.2 Setting up the simulation and test environment

In the project management interface, select "Options" under the "set PG/PC interface", select "PLCSIM MPI 1". Select "PLCSIM MPI 1" interface type, then save and exit the configuration interface, the configuration interface is shown in Figure 5-6.

Figure 5-6: Interface Configuration Interface

In the project management interface, click on the simulation icon to open the PLCSIM simulation interface, click on the Insert Input Variables, Insert Output Variables, Insert Memory Variables, Insert Timer, Insert Counter and other icons, respectively, to insert the windows of the corresponding variables, and in the window of the corresponding variables, according to the code, set up the variables displayed in the simulation interface as shown in Figure 5-7.
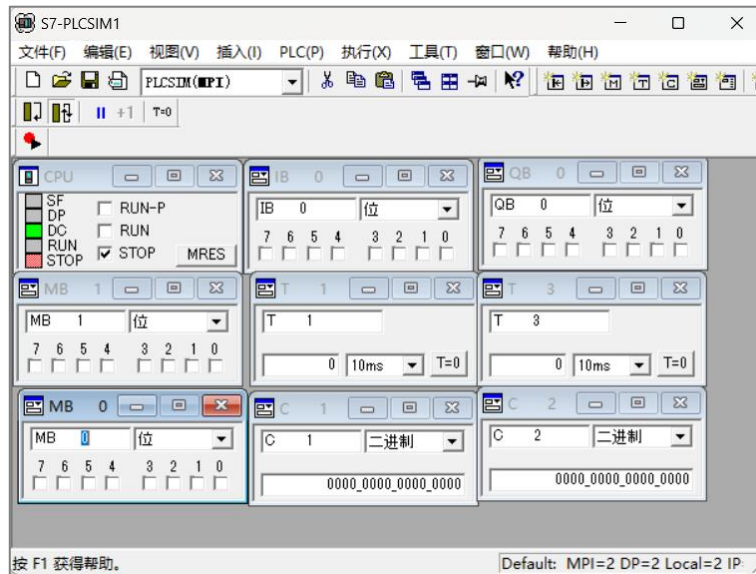

Figure 5-7: Screenshot of simulation interface

In the project management interface, click the download icon to download the hardware configuration and code into PLCSIM, and the screenshot of the download process is shown in Figure 5-8. Meanwhile, in the programme editing interface, click the download icon to download the code into PLCSIM after each modification of the programme.

Figure 5-8: Screenshot of the download process interface

Open the programme editing and compilation interface, click once on the "Monitor (on/off)" icon, the programme can be monitored, monitor the opening of the programme editing and compilation interface screenshot, as shown in Figure 5-9.
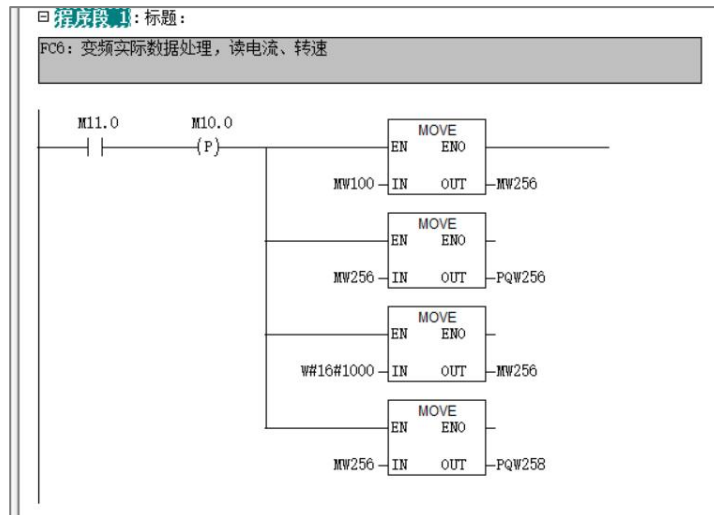

Figure 5-9: Edit compilation screen after monitoring is opened

5.2 Hardware Configuration

The hardware configuration of this course design is shown in Figure 5-11. Among them, slot 1 inserts the power supply module, and the power supply is "PS 307 5A"; slot 2 inserts the CPU module, and the CPU is "CPU315-2DP(1)"; slot 4 inserts the digital input/output module, and the digital input/output module is "SM323 DI8/DO8Xdc24V/0.5"; slot 4 inserts the digital input/output module, and the digital input/output module is "SM323 DI8/DO8Xdc24V/0.5". Slot 4 is inserted with digital input/output module, and the digital input/output module is "SM323 DI8/DO8Xdc24V/0.5A", and the start bit of input address (I address) is 0, and the start bit of output address (Q address) is 0.

Figure 5-11: Hardware Configuration Diagram

5.3 Programme validation

After establishing the simulation environment according to the debugging steps, build the ladder diagram for simulation. Click RUN to enter the run mode and the simulation starts running, the interface of simulation start is shown in Figure 5-12.
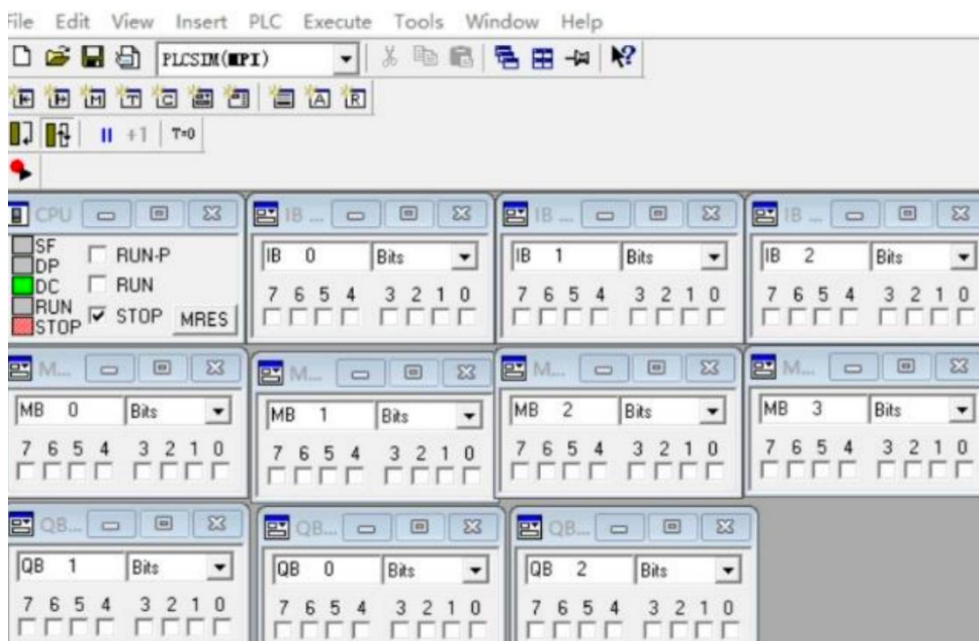

Figure 5-12: Simulation window interface

In the program editing window, click on the "monitor" (circled glasses icon in the figure) option, you can enter the program monitoring state, open the simulation interface click on "run", in the simulator interface in accordance with the software design of the order of the input signals selected In the simulator interface, select the input signals in the order designed by the software and input them, and observe whether the register signals and output signals are in line with the logic of the designed software programme.

After selecting the "monitor" option, the program editor interface enters the monitor mode, and you can see the output signals when the input signals are given in the simulator interface, and you can see the actual signal paths in the ladder diagram.

5.3.1 Recipe adjustment and speed adjustment

Figure 5-13: Recipe Adjustment Interface Diagram

During the testing process, the formula and motor speed can be adjusted and set, and the formula was successfully changed during the laboratory commissioning and the system operated normally with smooth mixing process.
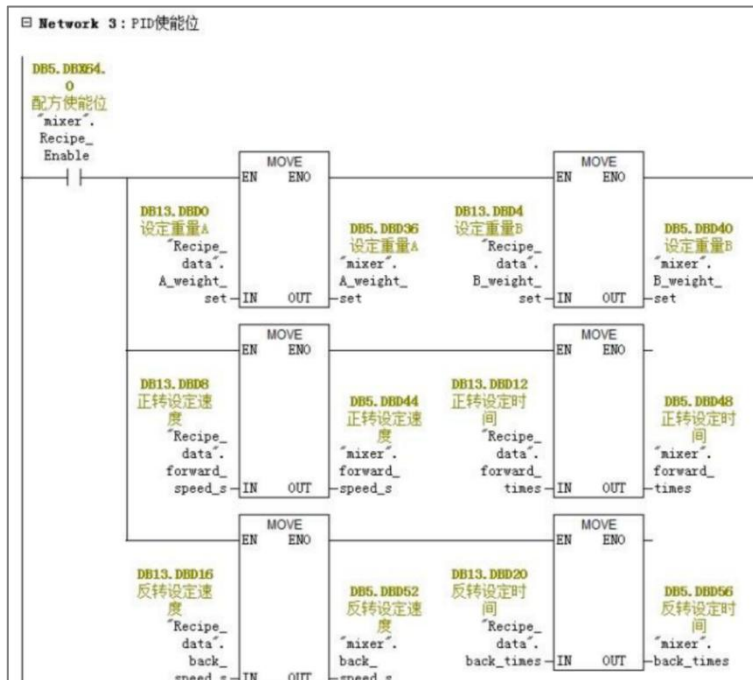

Figure 5-14: Ladder Diagram of Speed Programme

The mixer speed and mixing time were successfully changed during the measurement process, and the system operated stably without any abnormality.
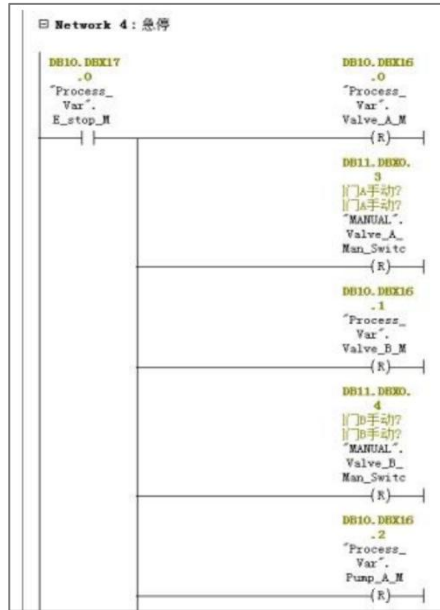
5.3.2 Emergency stop test

Figure 5-15: Emergency Stop Procedure Ladder Diagram

When the mixer is running normally during the test, you can press the emergency stop button to make an emergency stop and realise the function of emergency stop.

5.3.3 Functional debugging

(1) Feeding process

When the system is switched to the automatic mode, the system will start, first set the A valve automatic opening flag bit M9.0, start the A material pump with delay, then start the A valve status and A material supply pump, close the A valve and A material supply pump when the A material set value is reached, and then set the B valve automatic opening flag bit M9.1 to start the B valve status and B material supply pump to complete the B material feeding to the set value, and then complete the A material and B material dosing, and set the dosing completion bit M9.2. The B valve status and the B feed pump are activated to complete the B feed to the set value, completing the A and B feed, and setting the feed completion bit M9.2.
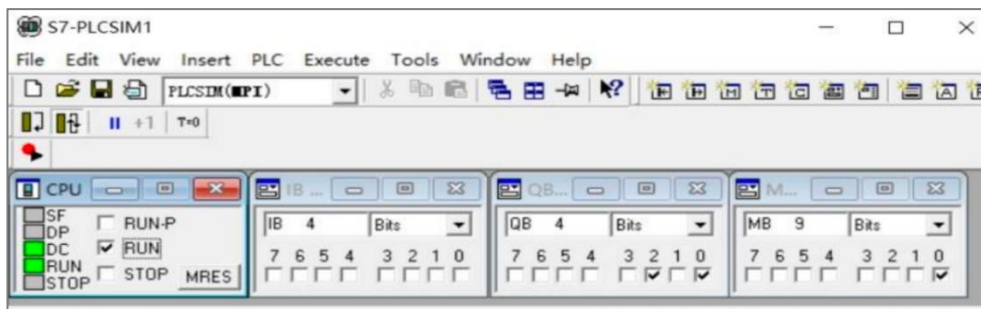

Figure 5-16: Automatic Mode, Adding A Material

Figure 5-17: Automatic Mode, Adding B Material

Figure 5-18: Automatic Mode, Dosing Complete

(2) Mixing process

After the feeding is completed, start the delayed mixing T10, reset the feeding completion bit M9.2 after completing the mixing, set M9.3 at the same time, the mixer starts to mix in the forward direction, reset M9.3 after completing the forward mixing, set M9.4 again, the mixer starts to mix in the reverse direction, and finally the mixing is completed, the delay is over, and set the mixing completion bit M9.5.

Figure 5-19: Positive Stirring in Auto Mode

Figure 5-20: Reverse Stirring in Automatic Mode

Figure 5-21: Stirring Completed in Automatic Mode