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Educational and scientific institute of energy saving and energy management
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Master's thesis

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according to the educational and professional program "Engineering of intelligent electrical and mechatronic complexes"
specialty 141 "Electric power engineering, electrical Engineering and electromechanics"
on the topic: " Modernization of the mine hoist control system "

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Kyiv – 2024

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TASK
for a master's thesis for a student
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1. Dissertation topic “Modernization of the mine hoist control system”, _____

supervisor of the thesis Viktor Gorodetskyi, PhD, assoc. prof, _____

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2. Deadline for the submission of thesis by a student 09.12.24

3. Object of study:___mine hoist_____

4. Subject of study: mine hoist control system _____

5. List of tasks that need to be done from the section «Research and Innovation»

1. Background and research significance of the subject Electric drive of a mine hoist
2. Structure and transformation scheme of electric control system of hoist
3. Realization method of hoist stroke control
4. Improving the design of electromechanical control system equipment.

5. Software design of mechanical and electrical control system
6. System Debugging
7. Participation at the scientific conference
8. Development of a startup project

6. The list of tasks that need to be done from the section «Developing of the startup project»

1.Project Background
2.Project Content
3.Goals and stages of implementation of the startup project
4.Demonstration of the relevance of the control system project and recognition of the innovation concept
5.Analysis of the Competitive Environment
6. Rationality of project resource allocation
7. Key Activities and Key Partners
8. Financial Justification of the Positioning Control System Startup Project
9. Target Groups of Potential Users for the Mine Hoist Positioning Control System
10. Identification of Potential Consumer Target Groups
11. Sales Channels for Mine Hoist Drive Systems
12. Business model of the project (equipment, technology)
13. Project Initiation Risk Analysis for Mine Hoist Drive System under new control
14. Evaluating Effectiveness and Attractiveness to Investors
15. Conclusions About Chapter

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Schedule

№	Name of the stages of the Master's thesis	The deadline for the stages completing of a Master's thesis	Note
1	Background and research significance of the subject Electric drive of a mine hoist	04.11.24	*done*
2	Structure and transformation scheme of electric control system of hoist	08.11.24	*done*
3	Realization method of hoist stroke control	14.11.24	*done*
4	Improving the design of electromechanical control system equipment.	20.11.24	*done*
5	Software design of mechanical and electrical control system	25.11.24	*done*
6	System Debugging	01.12.24	*done*
7	Participation at the scientific conference	20.11.24	*done*
8	Development of a startup project	09.12.24	*done*

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MODERNIZATION OF THE MINE HOIST CONTROL SYSTEM

Анотація:

Магістерська дисертація на тему «Модернізація системи керування шахтної підйомної установки»: 104 стор., 7 розд., 15 табл., 51 рис., 46 джерел.

Шахтний підйом в основному відповідає за транспортування персоналу, матеріалів і механічного обладнання в шахті. Це ключове обладнання, що з'єднує наземний і підземний простір шахти. Шахтний підйом повинен безперервно виконувати операції підйому та опускання в щоденному виробничому процесі шахти. Від того, чи буде її робота безпечною та надійною, залежить безпека виробництва шахти та безпека життя шахтарів. У разі виникнення несправності це може спричинити перерву у виробництві, пошкодження обладнання або навіть серйозні втрати, що матиме негативний вплив на суспільство. Тому до стабільності та безпеки електронної системи керування підйомником пред’являються жорсткі вимоги. Стабільність і безпека електричної системи управління підйомником стала важливою темою дослідження.

У цьому дослідженні детально обговорено процес комплексної модернізації електричної системи керування шахти на прикладі модернізації системи електричного керування вугільної шахти Baidong у Датуні, провінція Шаньсі,. По-перше, починаючи з технічних параметрів та підйомної системи, детально пояснюється структура підйомної системи та функції її компонентів. Далі в роботі аналізується схема електроприводу та формулюється схема перетворення системи електроуправління. За допомогою моделювання та імітаційного порівняння між алгоритмом ПІД-регулювання з нечітким адаптивним налаштуванням і традиційним алгоритмом ПІД-регулювання в алгоритмі інтелектуального керування підтверджуються переваги алгоритму ПІД-регулювання з нечітким адаптивним налаштуванням у впливі керування, і вказується, що алгоритм підходить для керування ходом підйомника. Для реалізайції

запропонованої модернізації обрано ПЛК серії S7-300 виробництва німецької компанії Siemens і конвертер виробництва компанії Shandong xinfengguang. У цьому дослідженні пояснюється організація програмної частини електронної системи керування з використанням програмного забезпечення STEP7. Показано використання сенсорного екрана для реалізації моніторингу робочого стану підйомника в реальному часі. На випробувальному стенді завершується налагодження електронної системи керування.

Рівень покращення електричної системи керування підйому має суттєвий вплив на ефективність виробництва шахти. Електрична система керування підйомом, яка використовує програмований логічний контролер (PLC) як основну систему керування і технологію перетворення частоти AC-AC, стала головним трендом розвитку у цьому напрямку в майбутньому.

Ключові слова: шахтний підйом; Електрична система керування; Нечітке адаптивне налаштування PID-регулятора; ПЛК; Регулювання частоти змінного струму.

Abstract:

Master's thesis on the topic "Modernization of the mine hoist control system ": 104 pages, 7 sections, 15 tables, 51 figures, 46 sources.

The mine hoist is mainly responsible for conveying the staff, materials and mechanical equipment in the mine. It is the key equipment connecting the ground and underground space of the mine. The mine hoist needs to continuously carry out lifting and lowering operations in the daily production process of the mine. Whether its work is safe and reliable affects the production safety of the mine and the life safety of the miners. Once a fault occurs, it may cause production interruption, equipment damage, or even major casualties, which will have a negative impact on the society. Therefore, the stability and safety of the hoist electronic control system are more stringent requirements. The stability and safety of electric control system of hoist has become a hot research topic.

Taking the upgrading of the electric control system of Baidong coal mine in Datong, Shanxi Province as an example, this study discussed in detail the comprehensive upgrading process of the electric control system of the mine. Firstly, starting from the technical

parameters and the hoist system, the structure of the hoist system and the functions of its components are explained in depth. Then, the paper analyzes the electric drive scheme, and formulates the transformation scheme of the electric control system. Through the modeling and simulation comparison between the fuzzy adaptive tuning PID control algorithm and the traditional PID control algorithm in the intelligent control algorithm, the advantages of the fuzzy adaptive tuning PID control algorithm in the control effect are confirmed, and it is pointed out that the algorithm is suitable for the stroke control of the hoist. After summarizing the programmable controller and high-voltage inverter, the paper finally determines the hardware selection, including the S7-300 series PLC produced by German Siemens and the cycloconverter produced by Shandong xinfengguang company. This paper further expounds the design of the software part of the electronic control system in the STEP7 programming software, and the configuration of the touch screen through the configuration software of the upper computer, so as to realize the real-time monitoring of the running state of the hoist. Finally, the debugging of the electronic control system is completed on the test bench.

The improvement level of the electric control system of the hoist has a decisive impact on the production efficiency of the mine. The electric control system of hoist, which uses programmable logic controller (PLC) as the core control system and AC-AC frequency conversion technology as the power transmission solution, has become the mainstream trend of development in this field in the future.

Key words: mine hoist; Electric control system; Fuzzy adaptive tuning PID; PLC; AC-AC Variable Frequency Speed Regulation.

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1 Introduction

1.1 Background and research significance of the subject

In coal mining, the mine hoist plays a core role. It mainly undertakes the task of transporting personnel, electromechanical equipment and materials from the ground to the underground and transporting them from the underground to the ground. Therefore, the mine hoist is known as the "lifeline" of the mine. The operation of the hoist is directly related to the production safety of the mine and the safety of miners' lives and property, and its stability is closely related to the safety and reliability of the electric control system. Only when a safe and reliable electric control system is installed can the hoist ensure the safe execution of the tasks of contacting the well and underground. Therefore, it is very important to design a reasonable, safe and reliable electric control system for mine hoist to ensure mine production.

A stable, safe, efficient, reliable and reasonable electric control system has a decisive impact on the production capacity and safety factor of the mine. At present, the electric control system of hoists in many domestic mines still relies on traditional relays, contactors and other old electrical components. These systems have problems such as large equipment volume, complex system wiring, heavy maintenance workload, high noise, high energy consumption and poor reliability. With the rapid development of China's economy and the growing demand for energy, these problems have seriously limited the production efficiency of mines.

In addition, in terms of speed regulation system of mine hoists in China, the traditional speed regulation mode of winding asynchronous motor rotor circuit series resistance is still widely used. This speed regulation mode adjusts the operation speed of the hoist by changing the resistance in series into the rotor of the asynchronous motor, but it requires a large number of resistance boxes, resulting in a large floor area and low reliability and stability of the control mode. In actual operation, the winder using this speed regulation scheme is prone to over winding, overspeed and other faults, which seriously restricts the production efficiency. At the same time, the state has been emphasizing energy conservation and emission reduction since the 13th five year plan, and this speed regulation scheme will convert a large amount of

electric energy into heat energy to be consumed in the resistance box during the speed regulation process, which is not in line with the requirements of the national energy conservation and emission reduction strategy.

In view of the above problems, it has become a top priority to seek a stable, reliable and efficient electric control system of mine hoist, and it is imperative to upgrade the traditional old electric control system.

As an important coal producing province in China, Datong is an important city in China's coal industry, with huge coal reserves and excellent quality, and is known as the "coal capital". The Baidong mine, located one kilometer southwest of Baidong village, Kouquan Township, southern suburb of Datong City, is adjacent to Tongjialiang Mine in the north and northeast of the mine field, and the siloogou mine field in the West and south. The mine field is about 6.3 kilometers long and 2.2 kilometers wide from northeast to southwest. It can provide a large amount of high-quality coal for China every year. However, due to the aging of the original electric control equipment in the mine, and the speed regulation mode of the traditional wound asynchronous motor rotor circuit in series with resistance, according to the national provisions on the production safety of coal enterprises and the requirements of Tongmei group for energy conservation and emission reduction, the existing electric control system has not met the standards, and it is in urgent need of transformation. Based on this background, the electric control system of Baidong mine has been upgraded.

1.2 Development and status quo of domestic enhanced electromechanical control system

As the core part of mine production, the performance of mine hoist system is directly related to mine safety and mineral production efficiency. In order to enhance the performance of the electric control system of the hoist, the key is to select a scientific and reasonable transmission mode to meet the production demand to the greatest extent.

Since the 1950s and 1960s, AC drive has been widely adopted in China. This kind of equipment has the advantages of low cost, simple operation and easy maintenance. But its speed regulation performance is poor, it is difficult to adjust, and it needs additional

transmission auxiliary equipment, which increases the input cost and makes the structure of the speed regulation system complex.

In the 1970s, with the expansion of the scale of China's mines and the substantial increase of annual mineral output, the traditional AC drive mode has been unable to meet the production demand of the hoist. It is urgent to find a new electric drive mode to meet the loading capacity and performance requirements of the hoist. At this time, the DC drive mode came into being.

DC drive modes mainly include generator motor drive and thyristor rectifier drive. Compared with the thyristor drive mode, it will cause greater reactive impact on the power grid during the rectification process, resulting in significant voltage drop. In order to improve the power factor, the motor is usually driven by two groups of thyristors in series. After optimization and improvement, this mode has the advantages of wide speed regulation range, smooth regulation curve, fast system response, low failure rate, simple maintenance, small volume occupation and so on. Therefore, the electric control system uses DC transmission mode to improve the coordination of the lifting process. The lifting speed of the motor is not affected by the load, and the hoist can still keep stable at low speed; In the deceleration phase, mechanical energy can be converted into electrical energy and fed back to the grid. However, the initial investment of this electronic control system is large, and the equipment cost is high.

With the rapid development of electronic power and computer control technology, large-scale integrated circuits and intelligent integrated chips are widely used in many fields. The power electronic converter is also integrated into the electrical control system of the mine hoist. Combined with the traditional AC drive technology and the increasingly perfect computer control technology, the efficient electric control system of the mine hoist has changed the situation of relying on DC drive technology in the past. AC motor is easy to operate, without frequent inspection and maintenance of brushes and motors, without commutation restrictions, and will not affect the transmission capacity and speed of the motor, so AC speed regulation scheme is gradually becoming the focus.

In recent years, variable frequency speed regulation technology has also been applied to the electric control system of hoist, which does not need to consider the energy loss on the rotor series resistance, and significantly improves the energy conversion efficiency. AC

variable frequency electric control system has the characteristics of large lifting capacity, wide adjustment range and high power factor, which has been widely recognized by many experts and scholars.

1.3 Improve the future development direction of electromechanical control system

After years of evolution, the development trend of electric control system of mine hoist is mainly manifested in the following points:

First of all, the stability and accuracy of the system adjustment speed have been significantly improved. When the mine hoist is faced with huge load fluctuation and wide speed regulation range, the electrical drive system must ensure that the speed can be adjusted smoothly while meeting the lifting process requirements. In terms of speed regulation accuracy, the hoist should have a low static slip to ensure that the speed can be accurately controlled within a predetermined range under different load conditions. This not only helps to prevent the accidental fall of the lifting container during the start-up process, but also reduces the crawling distance as far as possible while ensuring the safe and accurate parking, so as to improve the lifting efficiency.

Secondly, the perfection of fault monitoring device is very important. The electrical control system of mine hoist must have high reliability to avoid the impact of fault on the normal production of the mine, and even endanger the life safety of miners. The reliability of the electrical control system is mainly reflected in two aspects: first, the quality of the parts assembled by the electronic control system must be superior to greatly reduce the possibility of failure; The second is that the system can respond quickly when the fault occurs, and carry out isolation protection according to the nature of the fault, so as to facilitate the timely elimination of the problem. In order to further improve the reliability of safety protection, it is suggested to use "double line redundancy" technology for safety fault detection and treatment.

Third, the application of all digital control technology. With the introduction of microcomputer control system, the operation speed and storage capacity have been significantly improved. The advanced integrated circuit technology and the optimized combination of hardware and software have solved the defects of miniaturized digital control

in a new way, making full digital control the mainstream mode of hoist control. The application of full digital speed regulation technology realizes high-precision speed measurement in a large range. In addition, some control laws and methods that are difficult to be realized by analog circuits, such as optimal control, adaptive control and compound control, become simple and easy after using all digital control, which significantly improves the control performance of the system.

Finally, meet the requirements of four quadrant operation. The work of mine hoist is periodic, involving different stages such as acceleration, uniform speed, deceleration, crawling and parking, including forward electric and braking, and reverse electric and braking. Therefore, the electric drive system must be a reversible speed regulation system to achieve stable four quadrant operation.

1.4 Main research contents of this paper

Based on the development status of the electric control system of mine hoist in China, and taking the electric control system transformation project of Baidong mine in Datong, Shanxi Province as an example, this paper deeply discusses the design and research of the electric control system of mine hoist. The full text consists of seven chapters, and the contents of each chapter are summarized as follows:

The first chapter summarizes the research background, the development status and future trend of domestic hoist electronic control system, which provides the basis for subsequent research.

In the second chapter, starting from the main shaft parameters of Baidong mine, the composition and functions of the hoist system are described in detail. After comparing the four electric drive schemes, the transformation scheme of the electric control system is selected.

In the third chapter, the concept of lift stroke control is introduced from the speed chart of the hoist, and the fuzzy adaptive PID control technology is proposed to replace the traditional PID control technology. Matlab simulation proves the advantages of this technology in the hoist stroke control.

The fourth chapter mainly describes the hardware requirements of the transformation of the electronic control system, including the selection and design of the main control system PLC and variable frequency speed regulation system.

The fifth chapter describes the software design of the hoist electronic control system, including the PLC program design and the upper computer touch screen monitoring software program design.

Chapter 6 describes the commissioning process of the electric control system in detail, including the commissioning content and the simulated over winding protection test on the test bench.

Chapter 7 describes the contents of startup project in detail, and finally constructs an innovative and feasible business model through detailed planning of the implementation phase, analysis of the competitive environment, rational allocation of resources, clear target users and sales channels, and evaluation of risks and attractiveness.

The eighth chapter summarizes this paper, and looks forward to the future research direction, summarizes the main content of the article, and analyzes the existing shortcomings.

2 Structure and transformation scheme of electric control system of hoist

2.1 Main technical parameters of main shaft

In this paper, the electric control system of the main shaft in Baidong mine of Shanxi Datong Coal Mine Group Co., Ltd. is reformed and designed. The main technical parameters of the main shaft schematic diagram are as follows:

1. shaft Name: main shaft;
2. well depth: 98m vertical;
3. wellhead purpose: coal extraction;
4. shaft section: ϕ 6m;
5. derrick (tower) height: 30m;
6. crown wheel diameter: 3M;
7. hoist type: double drum winding type;

8. hoist model: 2jk-3/1.36;

9. elevator manufacturer: Shanxi XinFuSheng;

10. specification of lifting container: 4T bottom unloading type, 6T bottom unloading type;

11. type and specification of steel wire rope: 6V × 34- ϕ 34;

12. rated maximum static tension: 98000 n;

13. actual maximum static tension: 96016.48 n;

14. rated maximum static tension difference: 78400 n;

15. actual maximum static tension difference: 50936.48 n;

16. type and driving mode of safety brake: disc brake, spring driven;

17. model of hydraulic station: te160b;

18. matching reducer model: XL-30;

19. speed ratio of equipped reducer: 1:20;

20. model of main motor: yr500-8;

21. rated capacity of main motor: 500kW;

22. rated speed of main motor: 738rp.m;

23. stator voltage of main motor: 6000V;

24. main motor manufacturer: Nanyang explosion proof motor factory;

25. maximum lifting speed (rope speed): 5.45m/s;

26. primary lifting cycle time: 57s;

27. rated lifting capacity: 1.66 million tons;

28. comprehensive protection of hoist: m12-3b winch comprehensive protector kht5d;

29. wellhead and shaft signal device: KXT PLC lifting signal operation device;

2.2 Composition of hoist system

The hoist system in Baidong mine is composed of several key parts, including spindle device, reducer, lubrication system, hydraulic braking system (including hydraulic station and brake), motor, depth indication system and electric control system. The system schematic of these components is shown in Figure 1.

As the core working part of the hoist, the spindle device also undertakes important bearing tasks [12-13]. In daily operation, it is responsible for winding the steel wire rope and coping with the impact of various external forces. When the mine lifting demand increases, the spindle device will adjust the wire rope to adapt. The main shaft device of JK double drum hoist used in Baidong mine is composed of main bearing, main shaft, two rollers (including fixed roller and floating roller), four hubs, rope adjusting device and other key components.

In the hoist system, the reducer plays a vital role, which is mainly responsible for transmitting the power of the motor [14-15]. Through gear transmission, the reducer reduces the high-speed rotation of the motor to the low speed required by the hoist during lifting or lowering, and ensures that the drum has enough torque to maintain normal operation. The reducer selected by Baidong mine is XL-30 reducer with a reduction ratio of 1:20.

The lubrication system provides the necessary lubricating oil for the mechanical gears of the hoist system to ensure that the tooth surface is fully lubricated, reduce the friction loss in work, and extend the service life of the hoist. The lubrication system of Baidong mine is equipped with two sets, one for daily operation and the other for emergency standby. Once the main lubrication system fails, the standby system will start quickly.

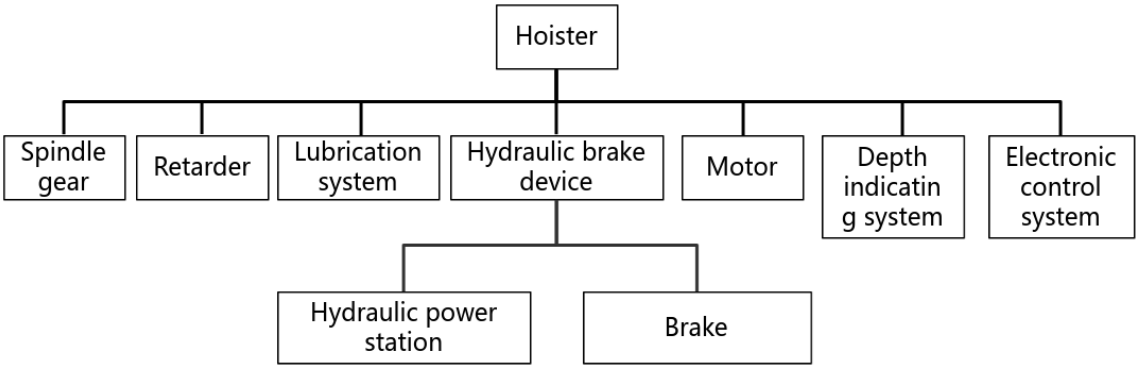

Figure 1: Mine hoist system

The hydraulic braking system is mainly composed of hydraulic station and brake. As the core of the safety control of the hoist, the hydraulic station usually works together with the disc brake to form the braking system [16-18]. The model of Baidong mine hydraulic station is TE160, and its main functions are as follows:

In order to provide braking torque of different sizes, the hydraulic station needs to provide oil pressure of different pressures to the brake. In the process of safety braking, the hydraulic station can apply all braking torque to the hoist in two stages. In the first stage, the braking torque remains constant until the vehicle stops; In the second stage, all braking torque is applied, that is, the so-called constant torque braking.

During the rope adjustment operation, the hydraulic station will provide an appropriate amount of hydraulic oil to the rope adjustment hydraulic cylinder to complete the rope adjustment task. As the "power workshop" of the whole system, the motor is responsible for providing power for the working system. The rotation of the motor drives the rotation of the two rollers to complete the lifting and lowering tasks in the mine. The motor model used in this system is yr500-8, which is a wound rotor three-phase asynchronous motor with a center height of 500mm and 8 pairs of poles. Depth indicator is an important accessory device of mine hoist [19-20]. In China's mines, the commonly used depth indicators include arch type depth indicator and disc type depth indicator, and a few mines use digital depth indicator. Baidong mine adopts memorial archway type depth indicator, whose functions include the following three points:

It indicates the specific position of the lifting container in the mine, which is convenient for the operator in the operation room to observe and judge.

When the lifting container reaches the deceleration position, send a signal to brake and decelerate in time, and remind the operator by ringing the bell.

When overwinding occurs, safety braking can be carried out in time to ensure production safety. The site drawing of Baidong mine hoist system is shown in Figure 2

The hydraulic braking system is mainly composed of hydraulic station and brake. The hydraulic station is the key to the safety control of the hoist. It is usually used together with the disc brake to form the braking system [16-18]. The model of Baidong mine hydraulic station is TE160, and its main functions include:

In order to achieve different sizes of braking torque, the hydraulic station needs to provide oil pressure of different pressures to the brake. In the process of safety braking, the hydraulic station can apply all braking torque to the hoist in two stages. In the first stage, the

braking torque remains constant until stopping; In the second stage, all braking torque is applied, that is, the so-called constant torque braking.

When the rope adjustment operation is required, the hydraulic station will provide an appropriate amount of hydraulic oil to the rope adjustment hydraulic cylinder to complete the rope adjustment task. The motor is the "power workshop" of the whole system, which is responsible for providing power for the working system. The rotation of the motor drives the rotation of the two rollers to complete the lifting and lowering tasks in the mine. The motor model used in this system is yr500-8, which is a wound rotor three-phase asynchronous motor with a center height of 500mm and 8 pairs of poles. Depth indicator is an important accessory device of mine hoist [19-20]. At present, in China's mines, the commonly used depth indicators include memorial arch depth indicator and disc depth indicator, and only a few mines use digital depth indicator. Baidong mine adopts memorial archway type depth indicator, whose functions include the following three points:

Indicate the specific position of the lifting container in the mine, which is convenient for the operator in the operation room to observe and judge.

When the lifting container reaches the deceleration position, send a signal to brake and decelerate in time, and remind the operator by ringing the bell.

In case of overwinding, safety braking can be carried out in time to ensure production safety. The site diagram of Baidong mine hoist system is shown in Figure 2.

Figure 2: physical drawing of Baidong mine hoist system

2.3 Electric drive scheme of hoist electric control system

(1) In the application scope of the current domestic electric drive scheme, the hoist mainly adopts the following methods.

(2) (1) The operation principle of G-M DC reversible speed regulation system is shown in Figure 3. Under the premise of keeping the excitation current of the DC motor constant, the precise control of the speed of the DC motor can be achieved by adjusting the output voltage of the DC generator [21]. Since the 1960s, this speed regulation scheme has been widely used in mine production in China. This scheme not only perfectly realizes stepless speed regulation, but also realizes smooth conversion between electric and braking modes, and effectively meets the requirements of four quadrant speed regulation. In addition, it can also provide advanced reactive power compensation to the grid to improve the power factor. Despite the above advantages, the scheme also has some shortcomings. Because its operating efficiency depends on the efficiency product of DC generator and synchronous motor, the efficiency is low. In addition, the combination of multiple motors leads to large space occupation when installing the speed regulation system and large noise during operation. In case of failure or routine maintenance, the whole system needs a lot of maintenance work. Therefore, G-M DC speed regulation scheme is no longer the trend of future development.

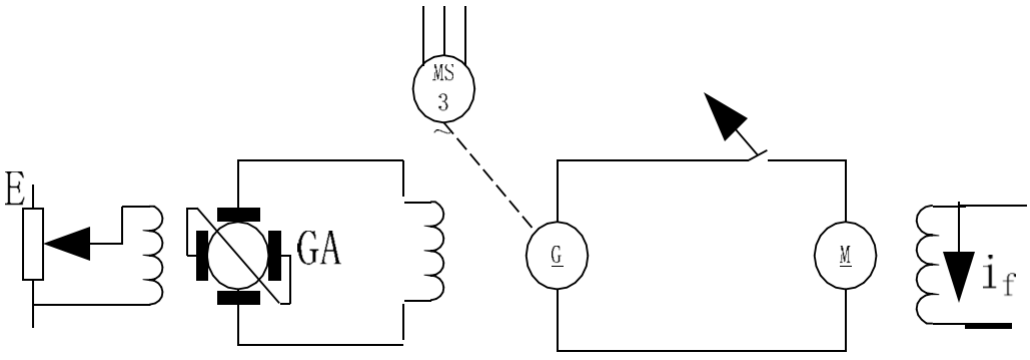

Figure 3: G-M DC reversible speed control system

(2) V-M DC reversible speed regulation system. The thyristor converter has replaced the rotary converter and greatly improved the operation efficiency. The schematic diagram is shown in Figure 4. In the figure, figure a shows the armature commutation speed regulation, and figure B shows the magnetic field commutation speed regulation. In the process of armature commutation speed regulation, because the magnitude and direction of the excitation

current remain constant, the torque of the motor can be adjusted by changing the output current of the armature converter. Its advantage is that the torque commutation is fast, but it also leads to the need to install two sets of armature rectifiers, which makes the overall equipment cost rise significantly. On the contrary, the principle of magnetic field commutation speed regulation is opposite to that of armature commutation speed regulation. It maintains the armature current direction unchanged and only adjusts the torque direction by changing the direction of excitation current. Although the torque reversal process of this method takes a long time, only one set of armature converter is needed, which reduces the overall equipment cost. Therefore, in order to save cost, this method is widely adopted in the case of low requirements for the speed of torque change.

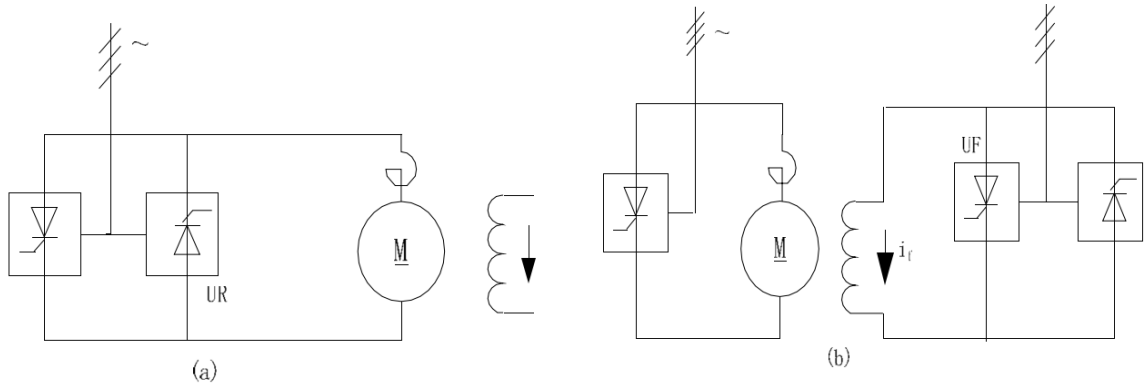

Figure 4: V-M DC reversible speed control system

(3) In the rotor circuit of asynchronous motor, the speed control system adjusts the speed through series resistance. This method only needs to switch the resistance box and change the value of the series resistance in the rotor circuit to complete the speed adjustment. Obviously, this is a step-by-step speed regulation method. However, in the process of speed regulation, large energy loss will continue to occur, which belongs to slip power consumption type. In addition, because the scheme can not provide smooth speed regulation effect, the efficiency is not high, and does not meet the national policy requirements of energy conservation and emission reduction, it is gradually being replaced.

(4) AC motor adopts AC-AC Variable frequency speed regulation system. As shown in Figure 5, the three-phase reversible rectifier bridge constitutes the core part of the AC-AC frequency converter. By accurately controlling the semiconductor switch, the voltage with variable frequency and amplitude is output to drive the motor to realize variable frequency

speed regulation [25-28]. Because the AC variable frequency speed regulation scheme has the advantages of wide regulation range, less maintenance demand and high power factor, it has become the preferred speed regulation scheme in the electrical drive transformation of many domestic mines.

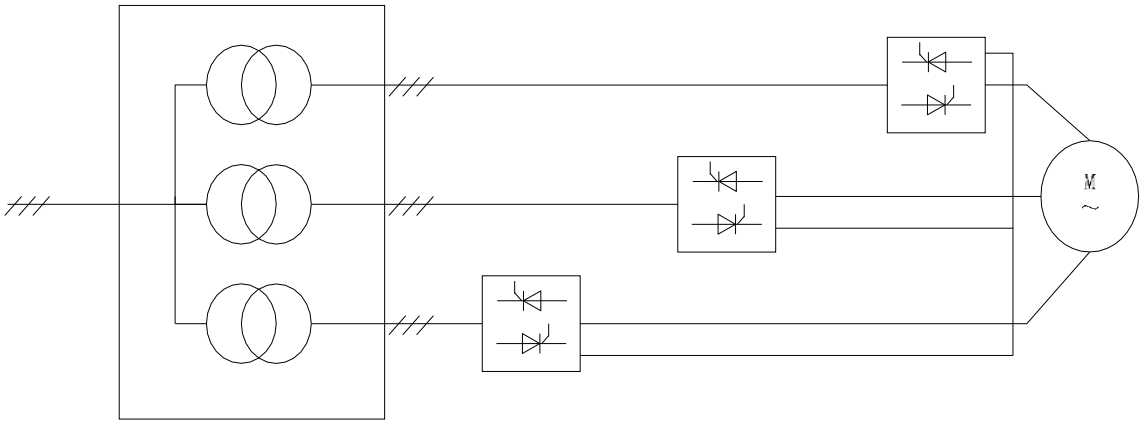

Figure 5: AC-AC Variable Frequency Speed Regulation System

In the past, the electric drive scheme of asynchronous motor rotor circuit series resistance speed regulation used in Baidong mine, because the resistance consumed a lot of energy in the speed regulation process, the work efficiency was very low. In view of the government's constant emphasis on energy conservation and emission reduction in recent years, the old electric drive scheme has been unable to meet the national energy-saving standards, so it is very necessary to adopt the efficient and energy-saving drive scheme. Considering the obvious advantages of AC-AC Variable Frequency Speed Regulation System in speed regulation performance and energy saving effect, as well as its full digital control ability, this electrical drive scheme decides to adopt AC-AC Variable frequency speed regulation system.

2.4 Improvement scheme for electric control system of hoist

In the electric control system of mine hoist in Baidong mine, the traditional TKD electric control system was originally used. However, because the system relies on outdated electronic components such as relays and contactors, it has many problems: huge equipment volume, complex system wiring, heavy maintenance work, high noise and high energy consumption during operation. These problems have seriously affected the production efficiency of the

mine, so it is very necessary to upgrade and transform the electric control equipment. PLC (programmable logic controller) has become one of the most popular controllers in the field of industrial control because of its wide application, powerful function and simple operation. The new electric control system uses two sets of Siemens S7-300 series PLC as the main control system, which constitute a redundant structure to ensure the stability of the system. In addition, the system also uses AC-AC Variable Frequency Speed Regulation Technology to control the speed of the hoist, uses Siemens et-200 as the signal acquisition system to collect field data, and is equipped with a world wide touch screen as the upper computer monitoring system. The structure diagram of the whole system is shown in Figure 6.

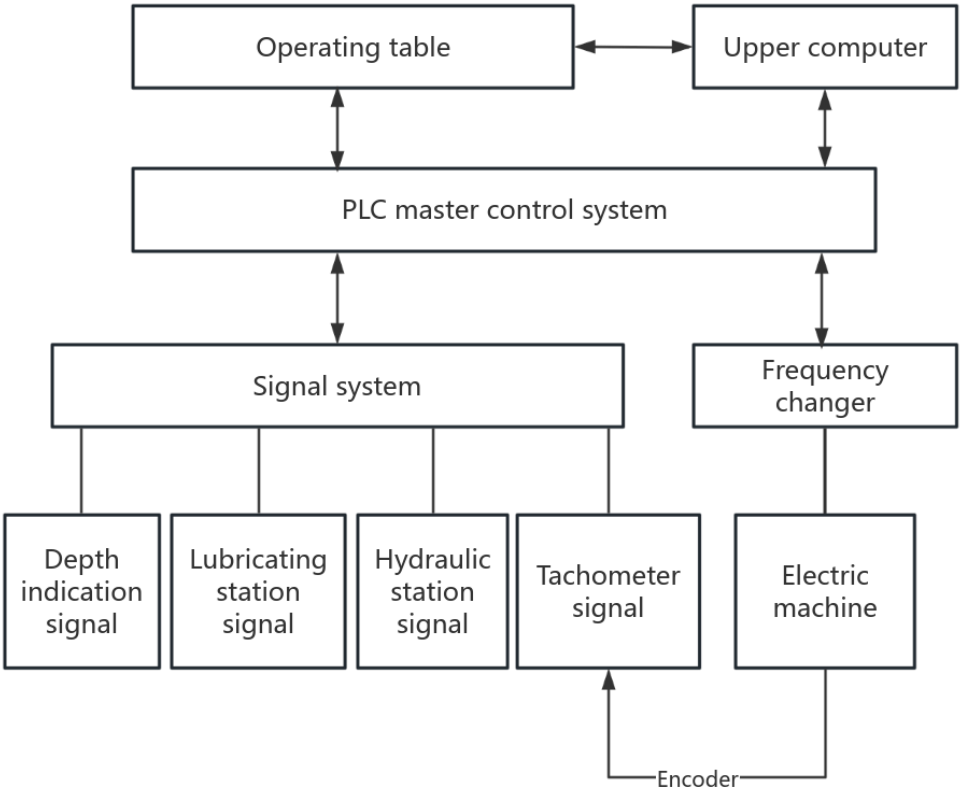

Figure 6: PLC master control system

Control core. In order to ensure the safety and stability of the mine work, this control core uses two sets of Siemens S7-300 backup design to realize the dual machine hot standby function. Under the normal working mode, two PLCs operate synchronously, one of which acts as the control core and the other is responsible for monitoring. The control core PLC is responsible for the input and output (i/o) of the system, while the monitoring PLC will lock its input and output ports when the control core PLC works normally. Even so, the monitoring

PLC will continuously monitor the operation status of the control core PLC and back up the data of the control core PLC. If the control core PLC fails and cannot continue to work normally, the monitoring PLC will quickly take over the control right and continue to operate the whole system to ensure that the system maintains the operation standard during normal production and avoid the occurrence of out of control faults.

Frequency conversion speed regulation system. The frequency conversion speed regulation system used in this mine is jd-bp37/38 series high-voltage frequency conversion speed regulation system produced by Shandong Xinfeng Electronic Technology Co., Ltd.

Signal acquisition system. The system is mainly responsible for collecting on-site signals, including the speed of lubrication station, hydraulic station, drum and motor, and the depth of the hoist. The collected signals will be sent to PLC for logic analysis and processing.

Upper computer monitoring system. The upper computer monitoring system is mainly responsible for monitoring the site operation, including the operation status and parameters of the hoist. By detecting and recording these data, the system can find potential problems in time, and alert the operator by sending an alarm, so as to ensure the smooth progress of mine production.

2.5 Summary of this chapter

This section first gives a detailed description of the parameters of the main shaft of Baidong mine and an in-depth explanation of each part of the hoist system. These parts cover the spindle device, reducer, lubrication system, hydraulic braking system (including hydraulic station and brake), motor, depth indication system and electric control system. After discussing the four common electric drive schemes in the hoist system, this section determines the scheme for the transformation of the electric control system. This scheme takes the PLC main control system as the core, uses the AC-AC Variable frequency speed regulation system as the electrical drive scheme, and realizes the real-time data monitoring of the whole system through the upper computer touch screen.

3 Realization method of hoist stroke control

3.1 Lifting speed diagram of the elevator

Hoist kinematics mainly discusses the interaction between lifting speed, acceleration, deceleration, lifting distance and lifting time [29]. In the process of operation, the hoist drives the lifting container to move up and down periodically in the mine, showing obvious regularity. Generally speaking, the regularity of the hoist movement can be revealed by drawing the relationship between the lifting container movement speed and time. This kind of chart is called the hoist lifting speed chart.

3.1.1 Determination of the ideal speed curve of the hoist

The lifting speed diagram is generally divided into two types: cage lifting and skip lifting. Baidong mine has selected the skip lifting mode. According to its lifting requirements, we have adopted the six stage speed chart shown in Figure 7, including:

Initial acceleration phase t0. In the initial stage of skip startup, in order to reduce the impact on the lifting system, the initial acceleration should not be too large. According to the coal mine industry standard, the maximum speed at this stage is limited to 1.5m/s.

Main acceleration phase T1. At this stage, the skip can run at a higher acceleration, and the speed usually increases from the initial speed v0 to the maximum speed VM.

Constant speed stage T2. The motor speed reaches the peak value, and the skip lifting speed also reaches and maintains the maximum value for uniform linear motion.

Deceleration phase T3. The skip is close to the wellhead. In order to prevent over winding failure during shutdown, the speed should be reduced from the maximum VM to the crawling speed v4.

Crawl stage T4. The skip is close to the wellhead, with a general distance of 2-5 meters. In order to ensure stable parking and safety, it crawls at a slower speed, and the crawling speed V4 is usually no more than 0.5m/s.

Braking stage T5. The skip reaches the wellhead and starts braking.

Parking rest phase θ. The hoist finishes braking and stopping, unloads coal and prepares for the next round of hoisting.

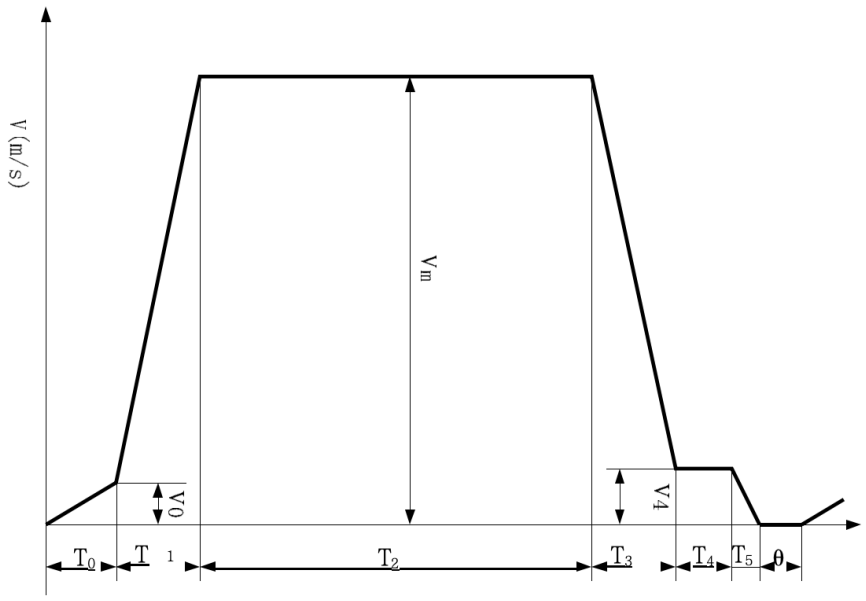

Figure 7: Velocity diagram

3.1.2 Calculation of hoist speed chart

Referring to the six stage velocity diagram shown in Figure 7, in order to design the parameters of each stage of the lifting system, we first need to understand the following key parameters: lifting height h, acceleration A0, A1, A3 and maximum lifting speed VM. According to the coal safety regulations, in general, the crawling distance in the crawling stage should be kept between 2 and 5 meters, and the crawling speed V4 should not exceed 0.5 m/s. As for the braking phase, the parking distance error between the skip and the unloading point should be controlled within ± 100mm to ensure the smooth parking and start-up operation. In the design case of Baidong mine, V0 is set at 1.2 m/s, the crawling distance H4 is 5 m, and the crawling speed is 0.4 m/s. The deceleration A5 in the braking phase is 1 m/s ², and the holding brake time is set as 1 s. With these parameters, we can derive the velocity map parameters listed in Table 1.

Table 1: Speed chart parameters

Promotion phase	Lifting parameters	Calculation formula
Initial acceleration	T_0	V_0/a_0

	H_0	$V_0^2/2a_0$
Main acceleration phase	T_1	$(V_m-V_0)/a_1$
	H_1	$(V_m+V_0)*T_1/2$
Crawling phase	T_4	H_4/V_4
	H_4	Set to 5m
Deceleration phase	T_3	$(V_m-V_4)/a_3$
	H_3	$(V_m+V_4)*T_3/2$
Isokinetic phase	T_2	H_2/V_m
	H_2	$H-H_0-H_1-H_3-H_4$
Braking phase	T_5	V_4/a_5
	H_5	$V_4*T_5/2$

3.2 Application of fuzzy adaptive PID control in lifting system

3.2.1 Introduction to fuzzy control principle

Fuzzy control is an intelligent control method, which is based on fuzzy set theory, fuzzy language variables and fuzzy logic reasoning [30]. Its decision-making process imitates human fuzzy reasoning and decision-making methods. Firstly, the fuzzy control method needs to transform the experience of operators or experts into corresponding fuzzy rules. Then, the signal collected from the outside is fuzzified as the input signal, and fuzzy reasoning is implemented in the fuzzy controller. Through fuzzy reasoning, the results are imported into the executive parts to realize fuzzy control.

Figure 8 shows the schematic diagram of fuzzy control. Fuzzy controller is the core component, which realizes the required control rules through software programming. The specific implementation steps of fuzzy control algorithm are as follows:

Precise acquisition. In order to achieve good control effect, the control system must accurately collect the controlled quantity.

Fuzzification of fuzzy interface. For fuzzy control, the external input signals must be fuzzified, otherwise the fuzzy controller cannot recognize these signals. The fuzzification interface provides a platform to convert the external specific values into fuzzy vectors that can be recognized by the fuzzy controller. Generally, we will compare the collected signal with the given value to obtain the error signal, which will be used as the input of the whole system. Then, the error signal is fuzzified and converted into fuzzy variables required by fuzzy control. The fuzzy subset of fuzzy input variable E can be divided into five, seven or nine levels. The more grades are divided, the more accurate the fuzzy control quantity is. Taking the seven levels as an example, e can be expressed as {positive large, median, positive small, zero, negative small, negative medium, negative large}, or as {pb, PM, PS, Zo, NS, nm, Nb}. For the fuzzy subsets that have been divided, membership functions of different shapes can be used to describe them, usually triangular membership functions or Gaussian membership functions.

Fuzzy reasoning. In order to complete the fuzzy reasoning process, it is necessary to establish appropriate fuzzy control rules. The generation of fuzzy control rules reflects the unique wisdom of human beings. The control rules formulated according to the daily experience of experts, scholars or technical staff are more convincing. According to the established fuzzy rules, the system is reasoned reasonably and the required fuzzy control quantity is obtained.

Defuzzification interface defuzzification processing. After the fuzzy reasoning, although the reasonable conjecture result can be obtained, the result is still a fuzzy vector, which can not be directly used as the control output of the control system. Therefore, the defuzzification interface must be defuzzified to convert it into a clear and accurate quantity that the system can recognize.

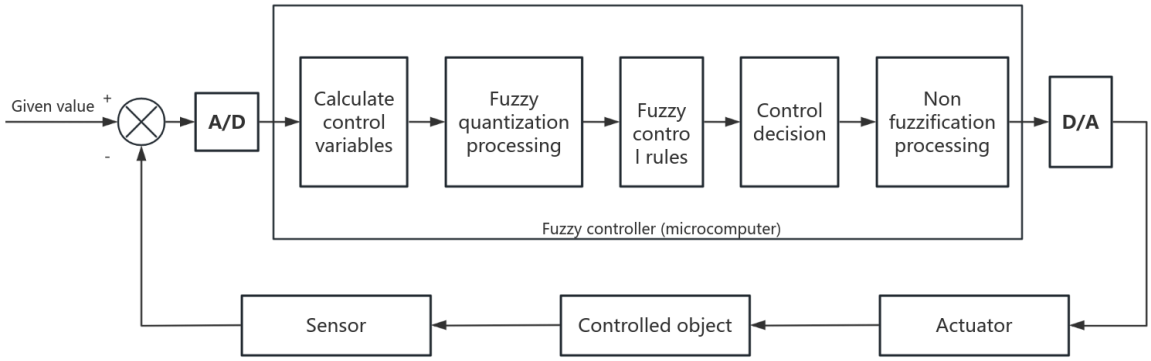

Figure 8: Schematic diagram of fuzzy control

3.2.2 Introduction to fuzzy adaptive PID tuning

In the industrial field, the traditional PID controller is widely used because of its excellent control effect. It consists of three core adjustment coefficients: proportional adjustment coefficient KP, integral adjustment coefficient KI and differential adjustment coefficient KD. Their respective roles are as follows:

Proportional adjustment coefficient KP. In order to ensure the rapid response of the control process, a high KP value is usually set. Its main function is to improve the adjustment accuracy by accelerating the system response speed. The greater the coefficient, the higher the accuracy of the system; However, if the KP value is too high, it may cause excessive overshoot and affect the stability of the system.

Integral adjustment coefficient KI. After the system reaches a stable state, there are often residual errors. The function of integral adjustment coefficient is to eliminate these errors. However, if the Ki value is too high, although it can quickly eliminate the static error, it may cause integral saturation, and then affect the stability of the system.

Differential regulation coefficient KD. When the system is unstable and dynamic, KD coefficient can predict and limit the variation trend of error, and enhance the dynamic performance of the system through continuous correction. However, if the KD value is too large, it may cause the system response process to brake too fast, prolong the adjustment time and reduce the anti-interference ability of the system.

Therefore, it is very important to reasonably set the fixed parameters of the traditional PID regulator to ensure the system performance to meet the requirements of dynamic and static performance.

In the previous discussion, we have explained the basic principle of fuzzy control and the working principle of traditional PID. Fuzzy adaptive tuning PID technology combines the advantages of traditional PID control and fuzzy control, aiming to achieve the best control effect of the control object. In order to effectively use this technology, we must deeply understand the model of the control object, and rely on the rich experience of experts or technicians to transform these experience into control rules. In addition, it is also necessary to model the rules to facilitate modeling, and complete the optimal adjustment of PID parameters through logical reasoning.

Usually, the fuzzy adaptive tuning PID controller takes error E and error change rate EC as inputs, and corrects the three parameters of PID control through fuzzy rule inference. This makes the entire control system have better performance compared to traditional PID controllers. Generally speaking, the structure of a fuzzy adaptive tuning PID controller is shown in Figure 9. The specific implementation steps of this control algorithm are as follows:

Firstly, the detected system error E and error change rate EC are fuzzified and converted into the quantity required by fuzzy control.

Then, through the reasoning of the fuzzy controller and the defuzzification of the anti fuzzy interface, the correction values of the three parameters of PID control, namely DKP, DKI and DKD, are obtained.

Then, add the correction quantities DKP, DKI, DKD and the initial system quantities *KP, *KI, *KD to obtain the adjusted KP, KI, KD values. Finally, these tuning parameters are input into the PID regulator to realize the control technology.

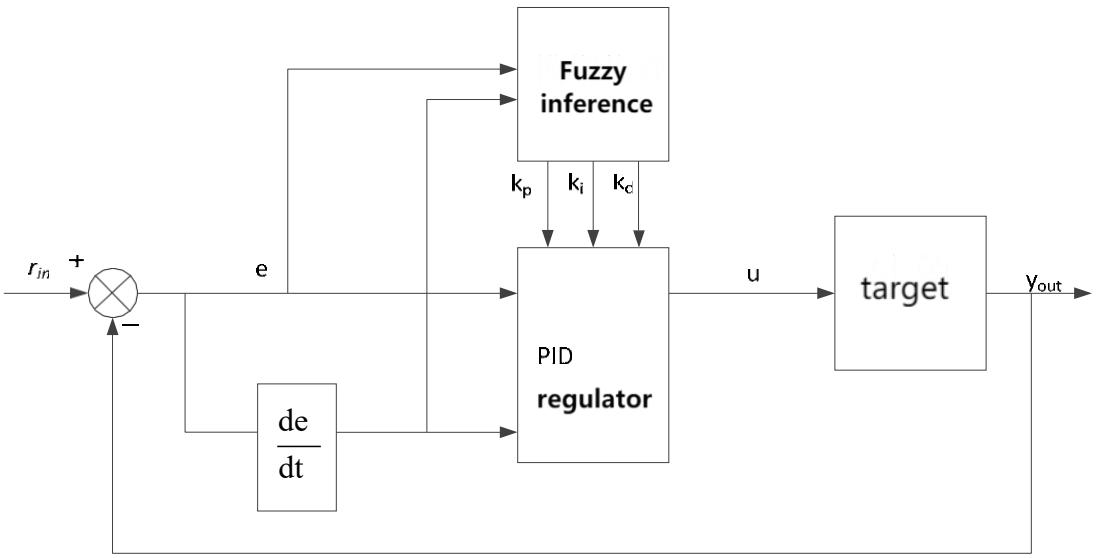

Figure 9: Structure diagram of fuzzy adaptive tuning PID controller

3.3 Design of fuzzy adaptive PID controller

Generally speaking, the process of building a fuzzy adaptive tuning PID controller includes the following four steps:

First of all, the structure of fuzzy controller should be clarified. In this case, the input variables of the fuzzy controller include error E and error change rate EC, and the output variables are three adjustment coefficients, namely DKP, DKI and DKD. Start MATLAB and enter the fuzzy command in the workspace to open the fuzzy control toolbox. In this toolbox, you can edit the controller structure. The controller structure edited in matlab fuzzy control toolbox is shown in Figure 10.

Then, it is necessary to define the fuzzy set of input and output variables and its universe. In order to ensure the accuracy of fuzzy adaptive PID control, in this case, the fuzzy sets of E, EC, DKP, DKI and DKD are divided into seven levels. Namely:

E={NB，NM，NS，ZO，PS，PM，PB}； EC={NB，NM，NS，ZO，PS，PM，PB}； dKP={NB，NM，NS，ZO，PS，PM，PB}； dKI={NB，NM，NS，ZO，PS，PM，PB}； dKD={NB，NM，NS，ZO，PS，PM，PB}；

The corresponding domains are:

The domain of E is {-6, -4, -2, 0, 2, 4, 6};

The domain of EC is {-6, -4, -2, 0, 2, 4, 6};

The domain of DKP is {-6, -4, -2, 0, 2, 4, 6};

The domain of DKI is {-6, -4, -2, 0, 2, 4, 6};

The domain of DKD is {-6, -4, -2, 0, 2, 4, 6};

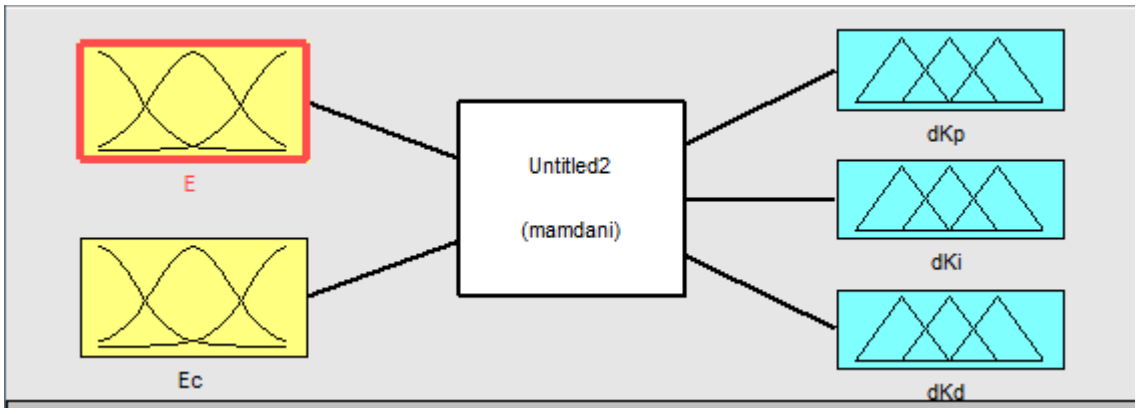

Figure 10: Fuzzy controller structure

Set membership functions of input and output. In this example, Gaussian membership functions are used for error E and error change rate EC, while triangular membership functions are used for DKP, DKI and DKD. The specific configurations of these membership functions are presented in the matlab fuzzy editor, corresponding to figures 11, 12, 13, 14 and 15 respectively.

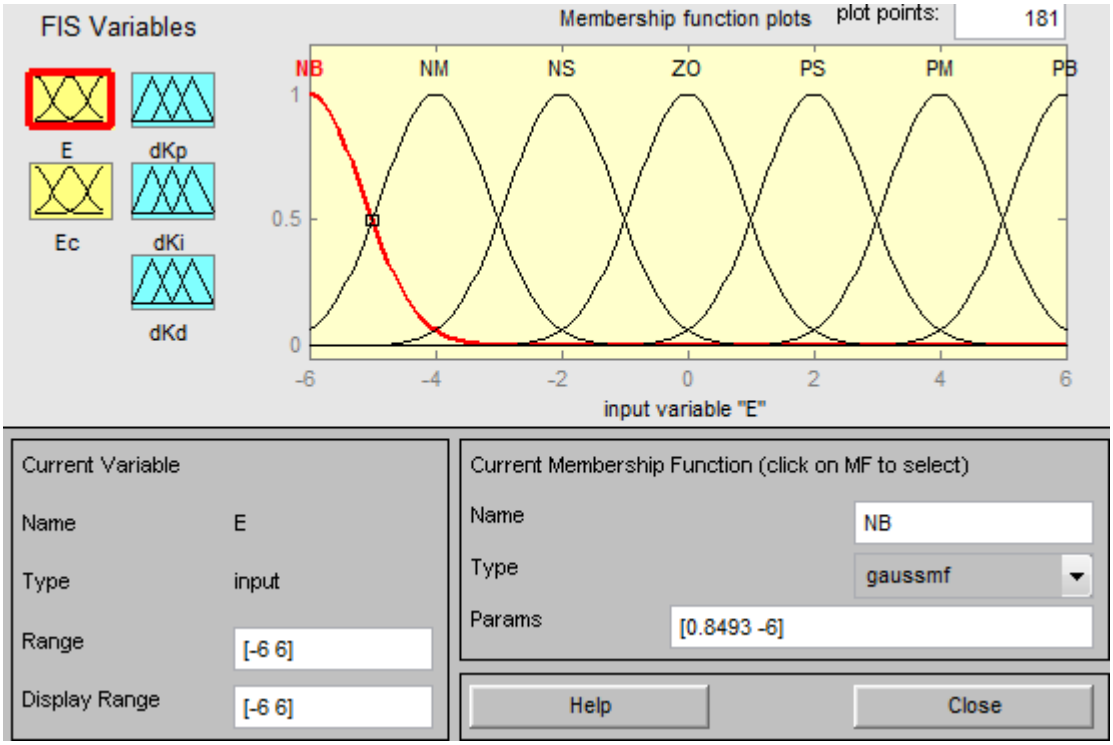

Figure 11: Membership function of error e

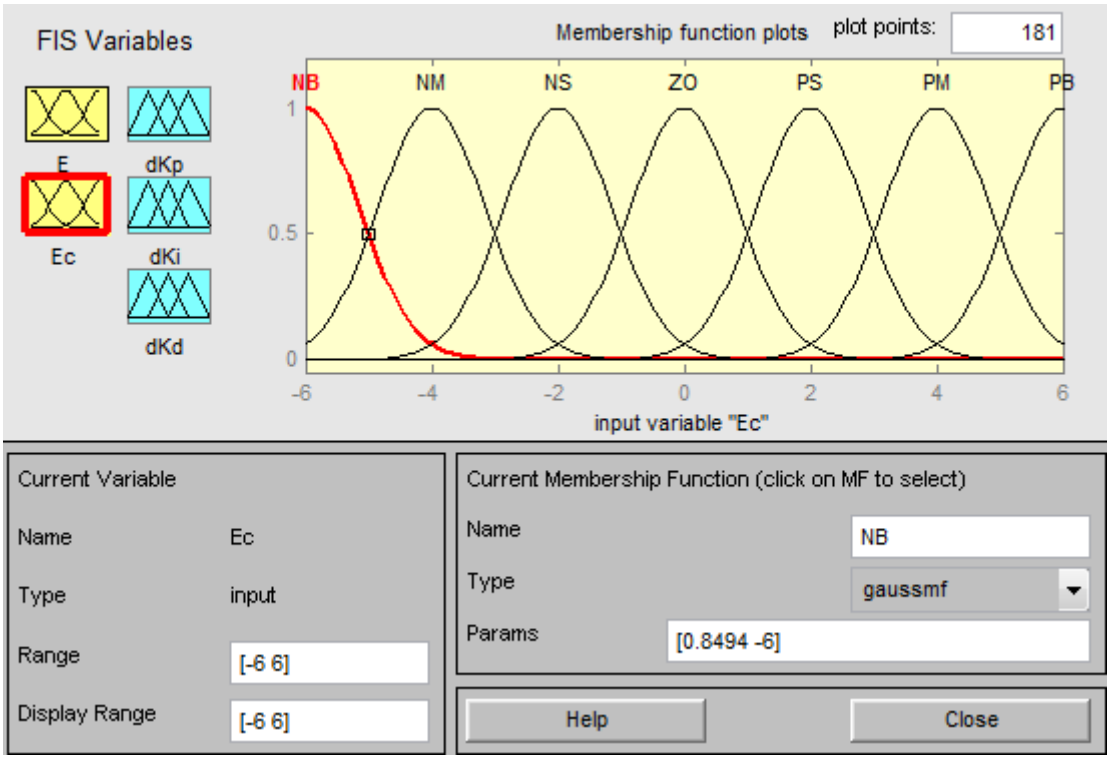

Figure 12: membership function of error change rate EC

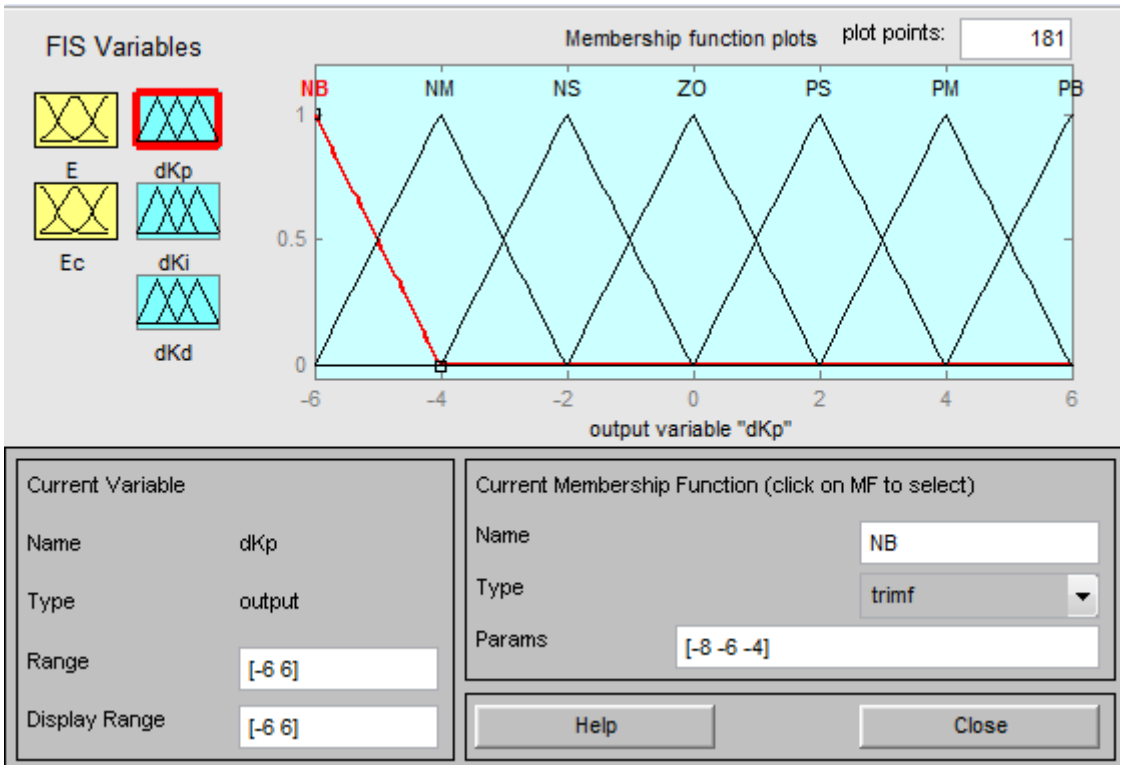

Figure 13: Membership function of proportional correction factor DKP

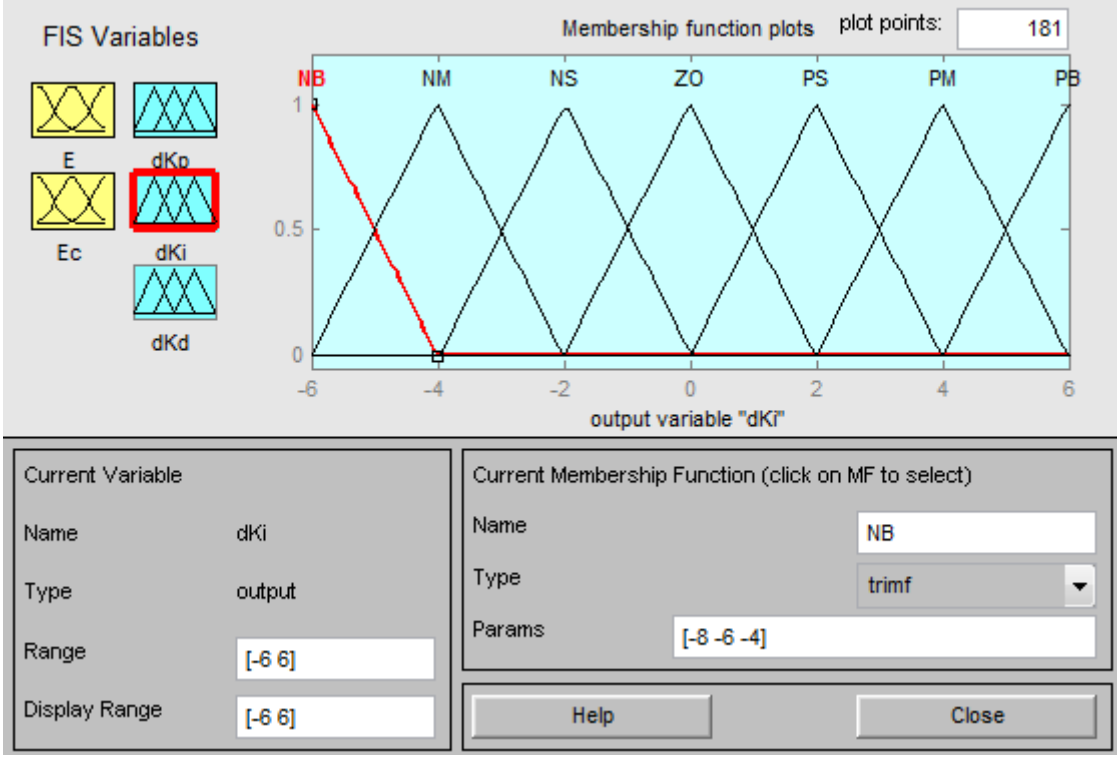

Figure 14: Membership function of integral correction coefficient DKI

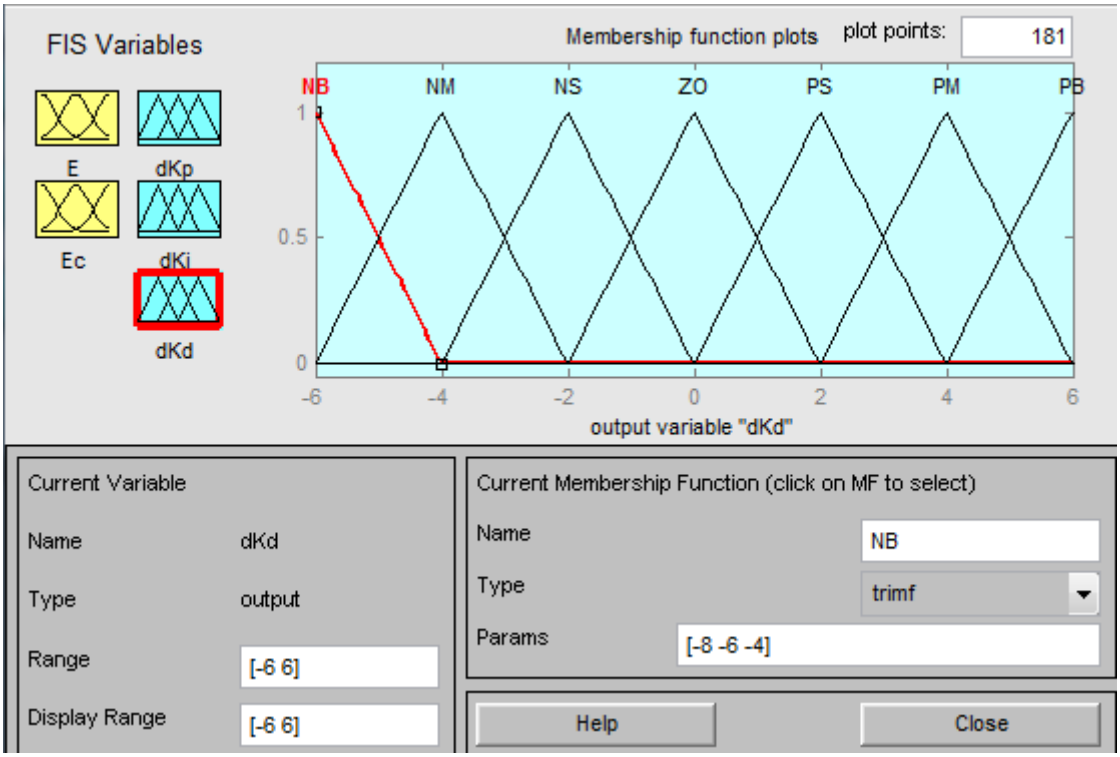

Figure 15: Membership function of differential correction coefficient DKD

A set of fuzzy rule control tables is created, and corresponding control strategies are formulated accordingly. Using the intuitive reasoning ability of experienced experts and human beings, and according to the real-time trend of error (E) and error change (EC)

generated by the system, the control strategy that can effectively reduce or even completely eliminate the error is formulated. Based on these strategies, you can further create corresponding rule tables. Combining the functions of KP, KI and KD mentioned in section 3.2.2, we can get the fuzzy rule tables of DKP, DKI and DKD as shown in Table 2, table 3 and table 4.

Table 2: Fuzzy rules of DKP

EC / E	NB	NM	NS	ZO	PS	PM	PB
NB	PB	PB	PM	PM	PS	ZO	ZO
NM	PB	PB	PM	PS	PS	ZO	NS
NS	PM	PM	PM	PS	ZO	NS	NS
ZO	PM	PM	PS	ZO	NS	NM	NM
PS	PS	PS	ZO	NS	NS	NM	NM
PM	PS	ZO	NS	NM	NM	NM	NB
PB	ZO	ZO	NM	NM	NM	NB	NB

Table 3: fuzzy rules of DKI

EC / E	NB	NM	NS	ZO	PS	PM	PB
NB	NB	NB	NM	NM	NS	ZO	ZO
NM	NB	NB	NM	NS	NS	ZO	ZO
NS	NB	NM	NS	NS	ZO	PS	PS
ZO	NM	NM	NS	ZO	PS	PM	PM
PS	NM	NS	ZO	PS	PS	PM	PB
PM	ZO	ZO	PS	PS	PM	PB	PB
PB	ZO	ZO	PS	PM	PM	PB	PB

Table 4: fuzzy rules of DKD

EC / E	NB	NM	NS	ZO	PS	PM	PB
NB	PS	NS	NB	NB	NB	NM	PS
NM	PS	NS	NB	NM	NM	NS	ZO
NS	ZO	NS	NM	NM	NS	NS	ZO
ZO	ZO	NS	NS	NS	NS	NS	ZO

PS	ZO	ZO	ZO	ZO	ZO	ZO	ZO
PM	PB	NS	PS	PS	PS	PS	PB
PB	PB	PM	PM	PM	PS	PS	PB

According to the previous rule table, 49 fuzzy adaptive PID control rules can be created in the rule editor shown in Figure 16. Once the fuzzy rules are formulated, the fuzzy controller is saved for subsequent simulation.

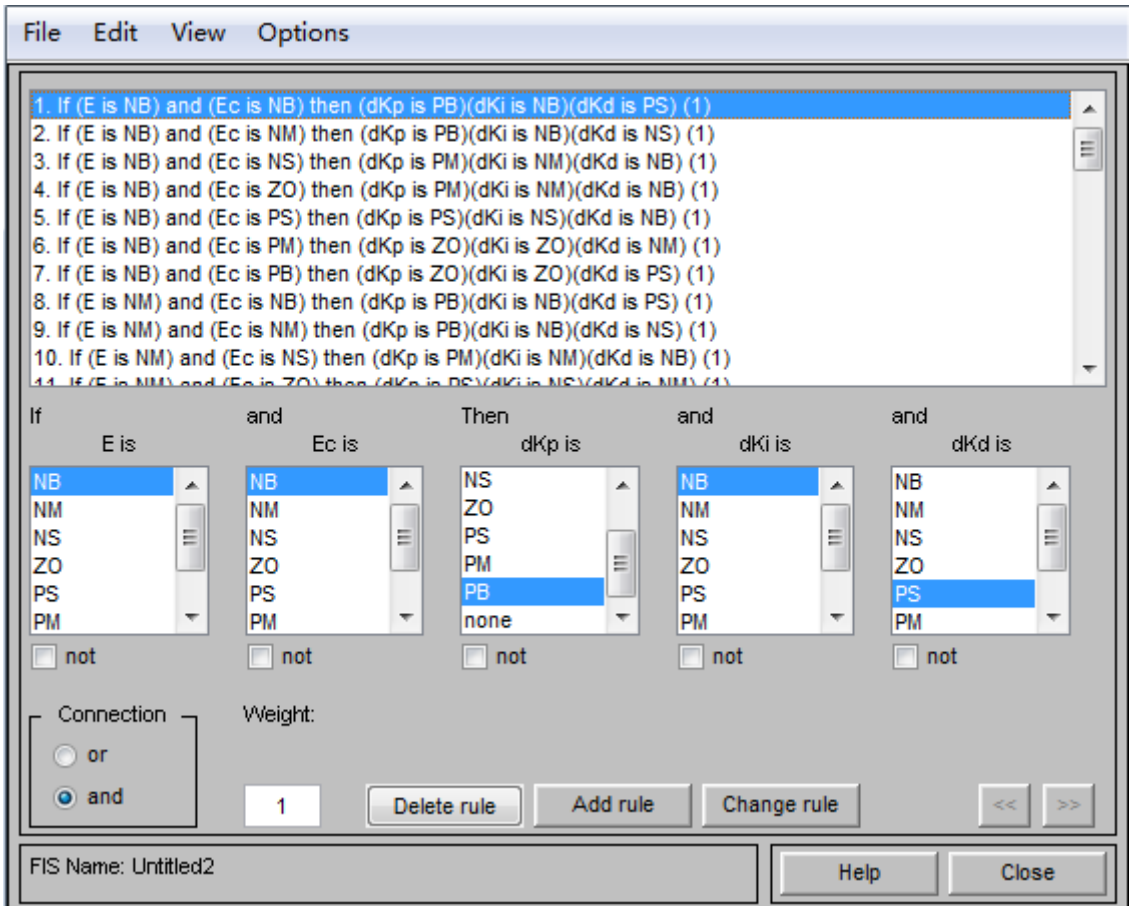

Figure 16: rule editor

3.4 Fuzzy adaptive tuning PID control simulation

3.4.1 Establishment of fuzzy adaptive PID and traditional PID simulation model

In the matlabsimulink environment, the model of fuzzy adaptive tuning PID control and traditional PID control can be constructed and simulated, and the system transfer function is set as follows:

$$G(S) = \frac{1}{2S^2 + 3.5S + 1} \qquad (3\text{-}1)$$

At the beginning, KP is set to 5, KI is set to 2, KD is set to 1, step signal is used as input, and ode23tb algorithm is used to build the model and simulate. The full view of the simulation model is shown in Figures 17, 18, 19 and 20. In Figure 18, the fuzzy adaptive tuning PID model is at the top, while the traditional PID model is at the bottom. Figures 18, 19 and 20 depict the specific configurations of subsystem 1, subsystem 2 and subsystem 3, respectively.

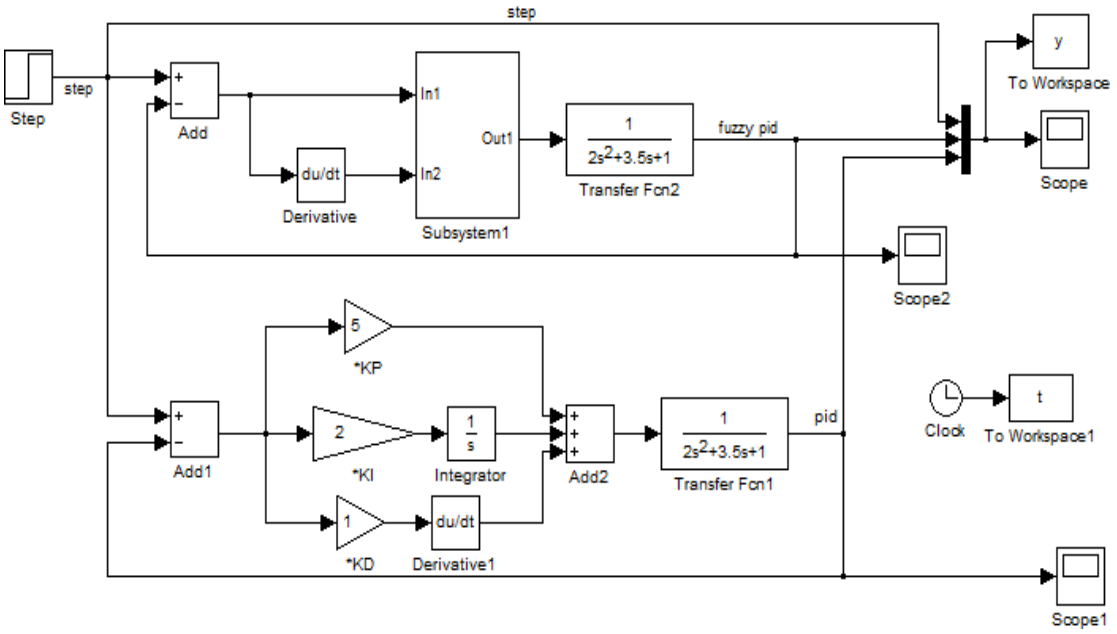

Figure 17: Fuzzy adaptive tuning PID and traditional PID simulation model

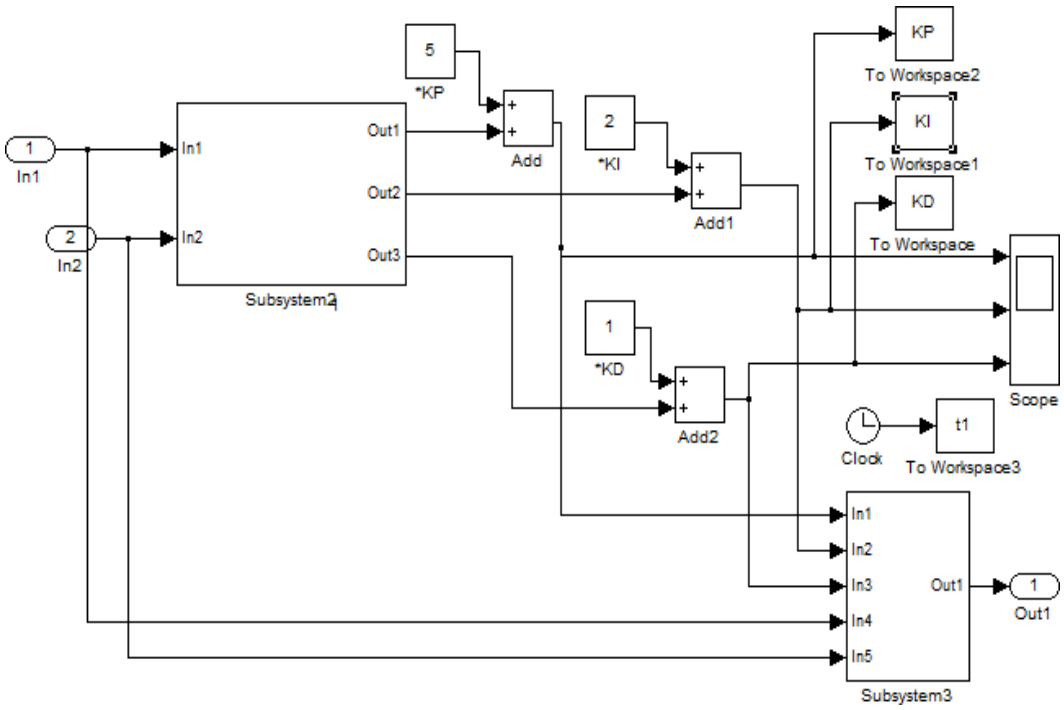

Figure 18: Subsystem 1 model

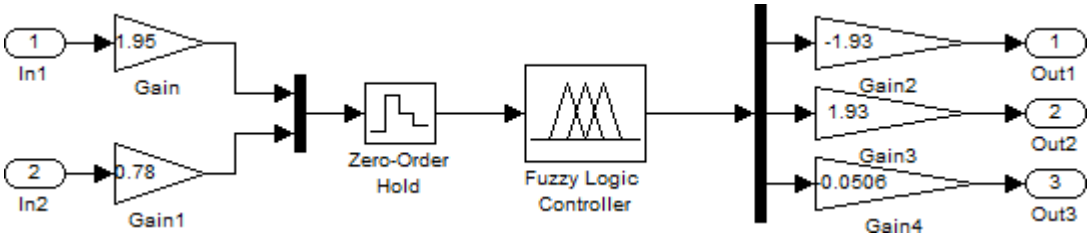

Figure 19: Subsystem 2 model

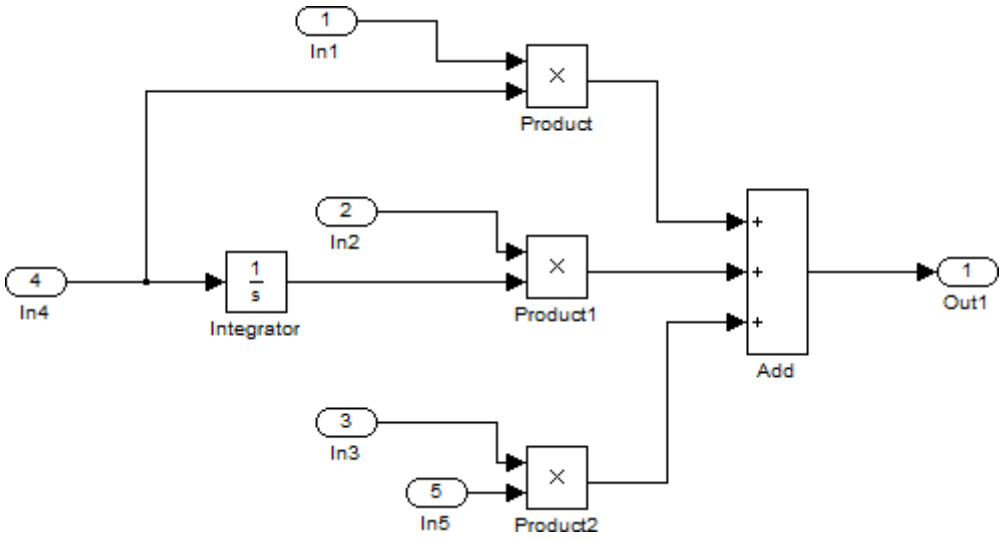

Figure 20: Subsystem 3 model

3.4.2 Comparison and analysis of simulation results

According to the above guidelines, the completed fuzzy controller .fis file must be loaded into the workspace of MATLAB, and then a complete simulation model is built according to the instructions in Section 3.4, and the system parameters are configured before the simulation process can be started. Through simulation, we can get the comparison diagram of the results of fuzzy adaptive tuning PID and traditional PID shown in Figure 21. The blue line in the figure represents the simulation waveform of the input step signal, the red line represents the simulation waveform of the traditional PID control, and the green line represents the simulation waveform of the fuzzy adaptive PID control. Through subsystem 1, we can see the specific numerical changes of KP, Ki and KD after adjustment. The simulation results are shown in figures 22, 23 and 24 respectively.

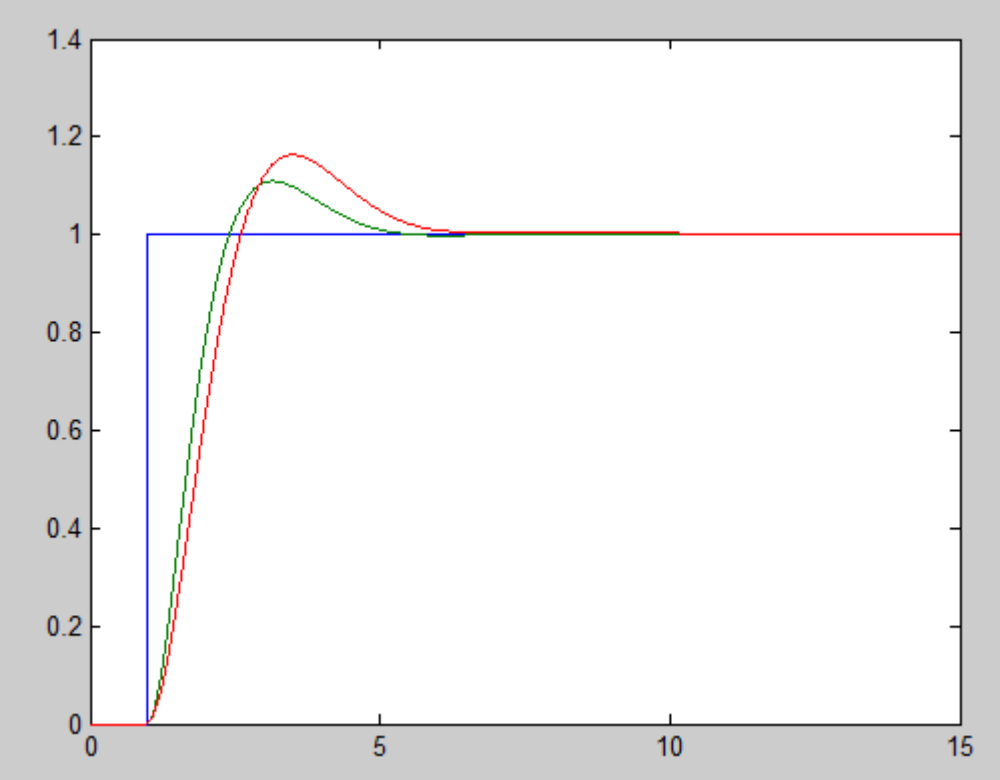

Figure 21: Comparison of simulation results of fuzzy adaptive tuning PID and traditional PID

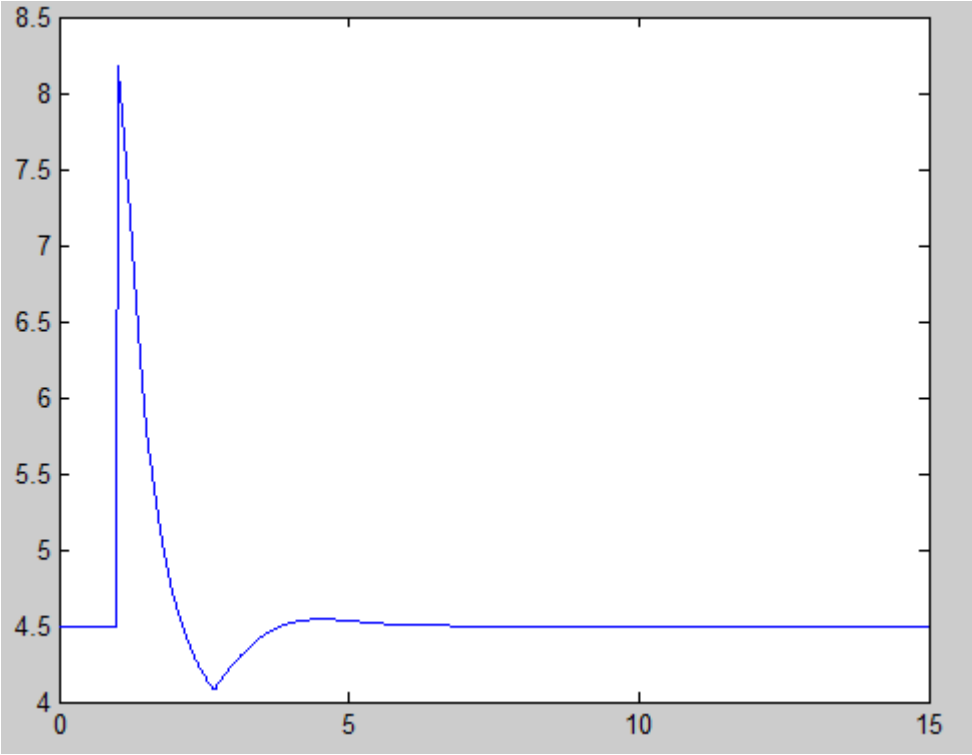

Figure 22: KP fuzzy adaptive adjustment value

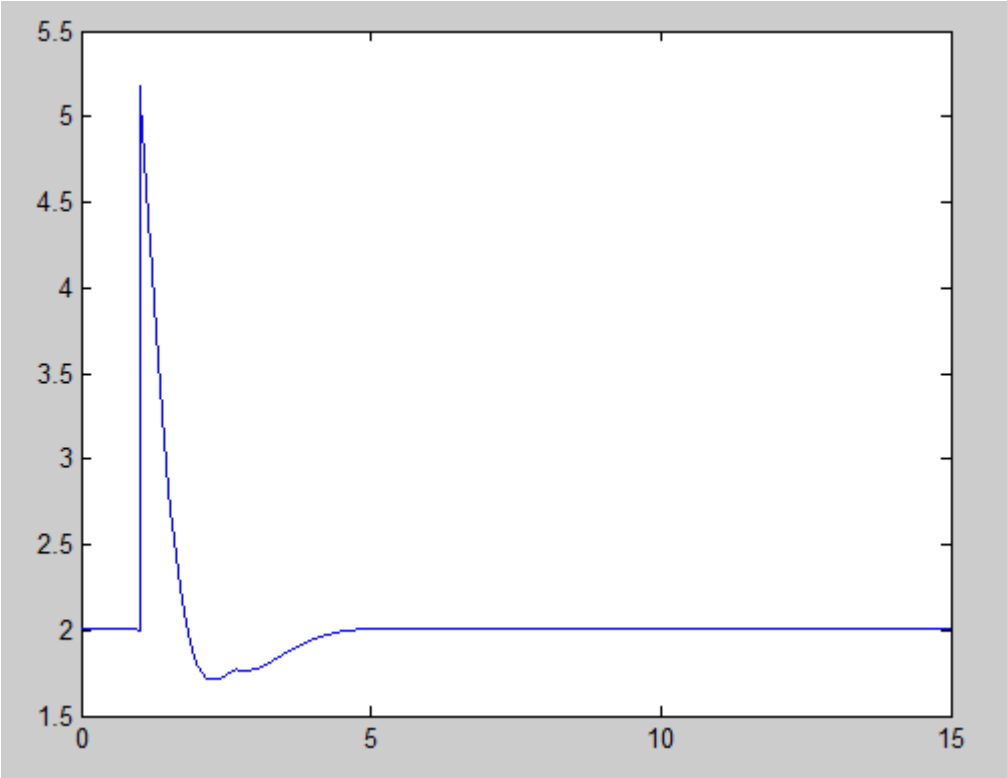

Figure 23: KI fuzzy adaptive adjustment value

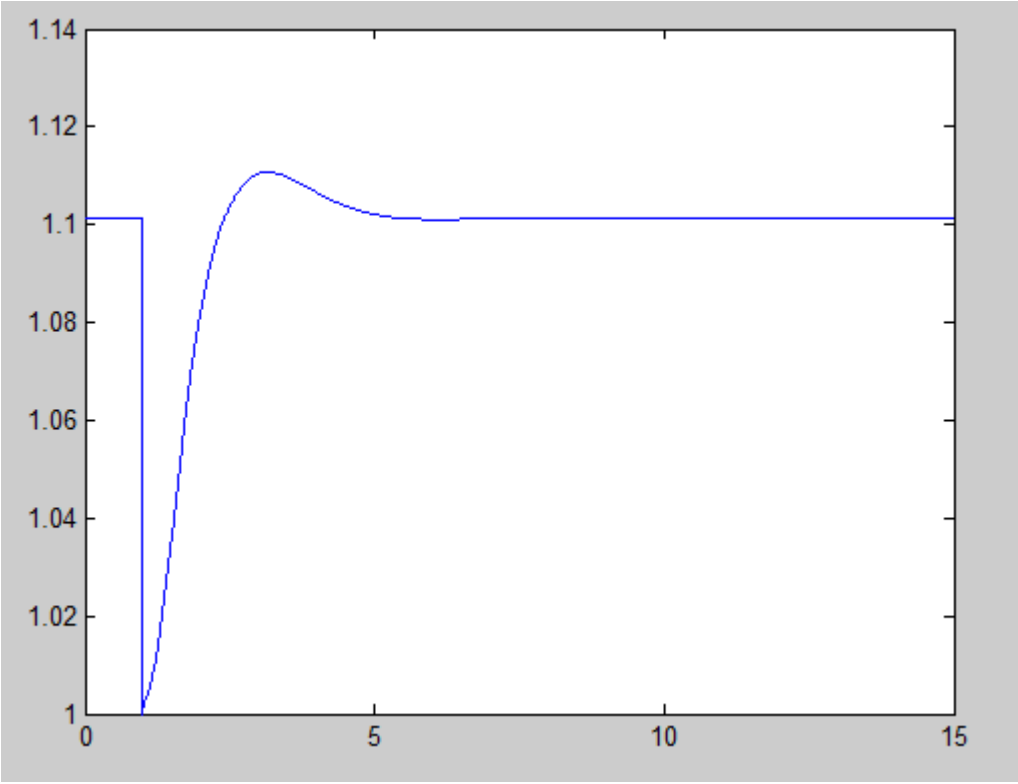

Figure 24: KD fuzzy adaptive adjustment value

It is found that compared with the traditional PID control technology, the fuzzy adaptive tuning PID control technology shows better dynamic and static characteristics in the system

regulation performance. Specifically, the fuzzy adaptive tuning PID control technology has a rapid response speed, can quickly reach a stable state, and compared with the traditional PID control technology, its overshoot is reduced. In addition, the time required to reach a stable state is significantly shortened, while maintaining high accuracy, which perfectly meets the control requirements of "stability, accuracy and speed". By analyzing the adaptive adjustment of KP, Ki and KD parameters, we can see that it is the fuzzy adaptive tuning PID technology that constantly adjusts these three parameters in the control process, so as to achieve the ideal control effect and carry out the optimal control of the control object. Therefore, in general, the fuzzy adaptive tuning PID control technology has better dynamic and static performance than the traditional PID control technology in system control.

3.5 Realization method of fuzzy adaptive tuning PID control

According to the analysis in section 3.4, if the mine hoist adopts the fuzzy adaptive PID control strategy to replace the traditional PID control, it will be able to control the hoist stroke more accurately. However, because the electric control system is based on S7-300PLC platform, it is difficult to write fuzzy rules in a short time, and there are challenges in editing membership function in PLC programming software, so it is difficult to achieve real-time online control. Even so, we can still use the off-line processing method to realize the fuzzy adaptive tuning PID control. The operation process is as follows: first, the control rules are processed offline and converted into a control query table instead of a control language; Then, save the query table in the data memory of S7-300PLC; When the system is running, the required PID parameter adjustment value can be quickly found through the look-up table method; Finally, these queried PID parameters are sent to the PID controller to complete the implementation of the intelligent control algorithm.

3.6 Summary of this chapter

This section first shows the hoist speed chart, and briefly describes the fuzzy control theory in the field of intelligent control and the principle of fuzzy adaptive PID control. With the help of matlab fuzzy control editor, we build a reasonable fuzzy adaptive PID algorithm

controller. Using matlabsimulink for modeling, we compared and analyzed the fuzzy adaptive PID algorithm with the traditional PID control algorithm. The simulation results verify the significant advantages of the intelligent control algorithm over the traditional PID algorithm, and summarize the method of applying this intelligent control algorithm to the hoist stroke control.

4 Improve the hardware design of the electromechanical control system

To improve the efficiency and efficiency of electromechanical control system, the optimization of hardware design is the key. This process mainly includes two main aspects: the first is the design of the main control system PLC, and the second is the design of variable frequency speed regulation system. In the design of PLC main control system, the core steps involve the precise selection of PLC to meet the needs of specific applications, and the appropriate configuration of i/o ports to ensure the smooth input and output of the system. In the design of variable frequency speed regulation system, we focus on selecting the appropriate high-voltage inverter, because it is directly related to the accuracy of motor speed control and the overall energy efficiency of the system. Careful selection of high-voltage inverter can ensure that the motor can maintain the best performance in different working environments, and then enhance the efficiency of the whole electromechanical system.

4.1 PLC Introduction

4.1.1 Overview of PLC development history

After nearly a hundred years of evolution, the traditional electronic control system has managed strong current signals by controlling weak current signals. However, in industrial production, the relay control system often has complex structure. Once a fault occurs, it is extremely difficult to locate and repair, which greatly affects the production efficiency. In order to meet the needs of the times, General Motors (GM) urgently developed a new industrial controller in 1968. It is more reliable, more comprehensive and more intuitive than the traditional relay. The following year, the United States successfully manufactured the

world's first programmable controller (PLC), which was designed to replace the relay, perform control tasks such as logic judgment, counting, timing, and quickly applied to the automatic assembly line of general motors.

The characteristics of PLC are mainly reflected in the following five aspects:

First of all, PLC has high reliability and strong anti-interference ability. As one of the key indicators of the electric control device, PLC adopts advanced integrated module control circuit technology, follows strict manufacturing standards, and is equipped with anti-interference modules, which significantly reduces the possibility of accidents. From the perspective of peripheral lines, the electric control system composed of PLC has significantly reduced the number of lines and contacts and further reduced the failure rate compared with the electric control system of relays and contactors of the same scale. In addition, PLC can automatically detect the performance of hardware and send out alarm in time when problems occur. In the program system, it can also realize the fault self diagnosis function of outer components, which makes the whole electric control system have the fault self diagnosis protection ability in addition to the PLC itself. Therefore, the electric control system using PLC has high reliability.

Secondly, PLC has comprehensive functions, complete supporting facilities and strong adaptability. Modern PLC can not only complete logic processing independently, but also accurately perform data operations, so it is more and more popular in the field of digital control. In recent years, the functional units of PLC are increasing, which makes it can be widely used in position servo control, temperature control, computer numerical control and other fields. With the progress of PLC in communication and man-machine interface technology, it becomes easier to build various control systems.

Third, PLC operation is simple and easy to understand. As a simplified version of industrial programmable computer, PLC is widely welcomed in industrial and mining enterprises. Its interface is easy to expand, and the programming language is easier for engineers to master. The ladder diagram language of PLC is similar to the schematic diagram of relay circuit, and only a few logic control instructions are needed to realize the relay function, which enables engineers who are not familiar with computer assembly language to skillfully apply PLC to industrial control.

Fourth, PLC is easy to modify, simple in design, convenient in composition and easy in maintenance. It discards the traditional wiring logic, adopts better storage logic, effectively reduces the number of external wiring, reduces the workload, shortens the industrial construction cycle, and makes maintenance more convenient. In addition, when the same equipment is used, the production process can be changed by changing the running program, which provides convenience for the diversified and small batch industrial demand.

Finally, PLC is light in weight, small in size and low in power consumption. At present, there are ultra-small PLC devices on the market, whose base size is less than 100mm, the overall weight is less than 150g, and the energy consumption is only a few watts. This small PLC device can be easily installed inside the equipment, which is helpful to realize the construction goal of mechatronics.

SIMATIC S7 Series PLC developed by Siemens has achieved significant benefits since its launch, including S7-200, S7-300 and S7-400 three sub series. Among them, S7-300 PLC has rich functions and can assist users in programming, startup and maintenance. Its main performance includes:

Extremely fast instruction processing speed. The processing time of product instructions is between 0.1 and 0.6 microseconds, and the processor can be compiled quickly.

Integrated human-machine interface. A simple and convenient man-machine communication control interface is integrated inside the product to realize efficient man-machine interaction.

Intelligent self diagnosis function. The CPU of S7-300 PLC has an intelligent diagnosis system, which can continuously monitor the normality of system functions and record errors and special system events.

Multi level password protection. In order to prevent unauthorized copying and modification, multilevel password protection mechanism is adopted to effectively protect technical secrets.

Therefore, S7-300 series PLC can meet the control requirements of medium and small scale. It has various performance modules, which can well meet and adapt to the automatic control requirements of the mine hoist electric control system. Its simple and practical distributed structure and universal network capability make the control application extremely

flexible. In addition, S7-300 PLC integrates a large number of functions, making it more powerful. Therefore, S7-300 series PLC is adopted in the design of the electric control system.

4.1.2 S7-300PLC hardware system composition and selection

As shown in Figure 25, S7-300 series hardware system is composed of multiple core components, including power module, central processing unit, signal module, function module, interface module, communication processor and various additional components [35-37].

Power supply module (PS): This module provides system power, signal power and bus power for PLC, and is the logistics supporter of PLC.

CPU module (CPU): as the calculation and control core of PLC, CPU bears the responsibility of the highest commander of PLC system.

Signal module (SM): the function of the signal module is similar to that of human sensory and vocal organs. PLC obtains information through the input module, makes decisions accordingly, and then sends control instructions through the output module. The signal module mainly includes the following input and output types:

Digital input module (DI): DC24V or ac120/230v power supply is usually used;

Digital output module (do): DC24V or ac120/230v power supply is also used, and relay is usually used as output device;

Analog input module (AI): usually supports voltage, current, resistance, thermocouple and other input forms;

Analog output module (AO): generally provides output in the form of voltage or current;

Function module (FM): This module mainly performs specific functions of PLC, such as counting, positioning, closed-loop control, etc.

Interface module (IM): im360, im361 and other interface modules are used to integrate multi-layer racks, realize the transmission between bus signal lines, and ensure the communication connection between various parts;

Communication processor (CP): This module provides network connectivity for PLC,

supports point-to-point, PROFIBUS, industrial Ethernet and other communication modes, and its role is similar to human social network.

Accessories: the additional accessories of S7-300 series PLC include line guide rail, bus connection structure, front connector, etc.

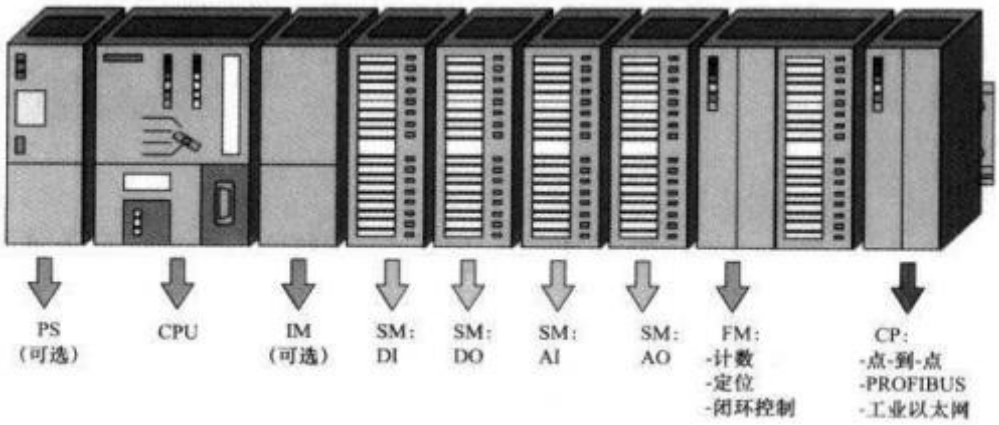

Figure 25: Hardware components of the S7-300 series

The electronic control power module used in this system is ps307 (5a), and its main technical characteristics are as follows:

(1) The module needs to be connected to a single-phase AC power supply with an input voltage range of ac120/230v and a frequency of 50/60hz;

(2) The output current is 5A and the output voltage is DC24V;

(3) It has stable isolation performance and conforms to en60950 standard;

(4) With short circuit and open circuit protection function;

(5) It is suitable for the use of load power supply.

The CPU module used in this system is compact cpu314c-2dp, and its main technical parameters are as follows: the user program memory capacity is 48KB, the maximum MCC is 8MB, and it supports free addressing. The number of digital i/o points is 992/992, the number of analog input and output points is 248/124, the instruction processing time is 0.1ms/1kb, the number of bit memory m is 2048, and the number of counters and timers are 256. The module integrates MPI and DP communication ports, but does not support PTP communication port. The CPU itself integrates 24/16 digital input and output points and 4+1/2 analog input and output points.

The digital input module of the signal module is sm321di32 × 24V, and the technical

parameters are as follows: 32 point digital input, live isolation, each 16 input points is a group, and the rated input voltage is DC24V. Suitable for switches and 2/3/4-wire sensors; The input "1" signal voltage range is 13~30V, and the input "0" signal voltage range is -30~5V. The typical value of input current is 7ma, and the module has no interrupting ability and diagnostic function. The typical value of module power consumption is 6.5W, and the length of signal cable can reach 600~1000m.

The digital output module is sm322do32 × 24v/0.5a. The technical parameters are as follows: 32 point output, live isolation, 1 group for each 8 output points, the maximum output current is 0.5A, the rated load voltage is DC24V, which is suitable for loads such as solenoid valves, DC relays and indicator lights. The minimum output "1" signal voltage is -0.8v, the current rating is 500mA, the maximum output "0" signal current rating is 0.5mA, the typical power consumption of the module is 4.9w, and the maximum length of the signal cable can reach 600~1000m.

The analog input module adopts sm331ai8 × 12 bits, and the technical parameters are as follows: 4 groups of channels, including 8 analog inputs, with optical isolation. The measurement methods (i.e. analog input signal type) that can be selected for each channel are voltage, current, thermal resistance or thermocouple, and support programmable interrupt, limit value monitoring and diagnostic interrupt functions. When the limit value is exceeded, programmable hardware interrupt can be triggered, and the connection with the backplane bus needs to be isolated.

The analog output module is sm332ao4 × 12 bits. The technical parameters are: it contains 4 groups of channel groups, the output points are 4, and the accuracy is 12 bits. It supports programmable interrupt and diagnostic interrupt. The output mode is voltage or current, which shall be isolated from the backplane bus connection.

Since cpu314c-2dp has integrated counters and communication modules to meet the requirements of electronic control, there is no need to configure additional function modules and communication processor modules in terms of hardware. The actual master PLC configuration hardware diagram is shown in Figure 26. This set of configuration is used as the main control computer, and the other set of configuration is completely consistent with the main control computer as the standby control computer. The two systems form a redundant

structure.

Figure 26: Hardware components of the S7-300 series

4.1.3 I/O distribution of the electronic control system

For the hardware wiring and software programming of the electric control system, the allocation of i/o ports is a crucial core link, especially in the design of the hoist hardware control system. This section will discuss the reasonable configuration method of i/o ports based on the master PLC configuration described in the previous section. In view of the specific environment of Baidong mine and the possible expansion requirements in the future, enough expansion space must be reserved when configuring the i/o port. At present, cpu314c-2dp is only equipped with digital output port (do). See Table 5 for detailed configuration. See tables 6, 7, 8 and 9 for the specific configuration of other i/o ports on site.

Table 5:DO configuration of the main control CPU

Serial number	Signal name	Symbolic name	Address
1	Retarding bell	JSL	Q 125.0
2	Soft safety loop relay	RAJ	Q 125.1
3	Allow speed given value	YSG	Q 125.2
4	Inverter scram signal	BJX	Q 125.3
5	Converter forward signal	BZSX	Q 125.4
6	PLC gating	PLC-Z	Q 125.5
7	Inverter reverse signal	BFSX	Q 125.6
8	Working brake release	GZJ-S	Q 125.7

Table 6:DI module configuration

Serial number	Signal name	Symbolic name	Address
1	Main fan starting	FQ	I 4.0
2	Main fan shutdown	FT	I 4.1
3	Lubrication station start-up	RQ	I 4.2
4	Stop of lubrication station	RT	I 4.3
5	Hydraulic station startup	YQ	I 4.4
6	Hydraulic station stop	YT	I 4.5
7	Lubrication hydraulic pressure starts at the same time	JQ	I 4.6
8	Lubrication hydraulic pressure stops at the same time	JT	I 4.7
9	High voltage closing	GYH	I 5.0
10	High voltage trip	GYT	I 5.1
11	Alternative mode selection	BYF	I 5.2
12	Semi automatic mode selection	BZDF	I 5.3
13	Manual mode selection	SDF	I 5.4
14	Maintenance mode selection	JF	I 5.5
15	Job selection	GZ	I 5.6
16	Rope adjustment selection	TS	I 5.7
17	Manual forward	SF	I 6.0
18	Manual reverse	SZ	I 6.1
19	Release direction	JF	I 6.2
20	Light fault	QGJ	I 6.3
21	Drive	KA	I 6.4
22	Forward inching	ZD	I 6.5
23	Reverse inching	FD	I 6.6
24	Stop	AN-TC	I 7.0
25	Test selection	SX	I 7.1
26	Hydraulic test	YS	I 7.2
27	Over roll test	GS	I 7.3

28	Rewinding reset	SGF	I 7.4
29	Lower overwind reset	XGF	I 7.5
30	Spare 11	BY-11	I 7.6
31	Spare 12	BY-12	I 7.7
32	Lubrication station heater manual	SRJ	I 8.0
33	Automatic lubrication station heater	ZRJ	I 8.1
34	Hydraulic station heater manual	SYJ	I 8.2
35	Hydraulic station heater automatic	ZYJ	I 8.3
36	Safety circuit closing	AC-IN	I 9.0
37	Fault start-up	GK	I 9.1
38	Zero position of brake handle	ZDL	I 9.2
39	Master handlebar zero position	ZSL	I 9.3
40	Master handle reverse	ZLF	I 9.4
41	Master handle forward	ZLZ	I 9.5
42	Emergency stop	CJT	I 9.6
43	Safety loop reset	AHF	I 9.7
44	Inverter loop interlock	BG	I 10.1
45	Hydraulic temperature too high	YY-WG-IN	I 10.2
46	Hydraulic temperature too low	RH-WG-IN	I 10.3
47	Frequency converter waiting for completion	BJ	I 11.0
48	Frequency converter alarm	QGB	I 11.1
49	Converter start	BQ	I 11.2
50	Converter forward	BPQ-ZX-IN	I 11.3
51	Inverter reverse	BPQ-FX-IN	I 11.4
52	Main fan power on	ZDH	I 12.0
53	No. 1 lubrication pump power supply closed	1RDH	I 12.1
54	No. 2 lubrication pump power supply closed	2RDH	I 12.2
55	No. 1 hydraulic pump power supply closed	1YDH	I 12.3
56	No. 2 hydraulic pump power supply closed	2YDH	I 12.4

57	Lubrication heater power on	RJDH	I 12.5
58	Hydraulic heater power on	YJDH	I 12.6
59	Backup power switch on	BYDH	I 12.7
60	AC 110V power switch on	AC110H	I 13.0
61	Transmission control power on	CKDH	I 13.1
62	AC 220V power switch on	AC220H	I 13.2
63	UPS power switch on	UDH	I 13.3
64	Switch on of gate control power supply	ZKDH	I 13.4
65	Circuit board power on	DBDH	I 13.5
66	Di module power on	DIDH	I 13.6
67	Do module power on	DODH	I 13.7
68	Main fan contactor closing	ZFJH	I 14.0
69	Contactor of No.1 lubricating pump is closed	1#RJH	I 14.1
70	Contactor of 2 lubricating pump is closed	2#RJH	I 14.2
71	1 hydraulic pump contactor closing	1#YJH	I 14.3
72	2 hydraulic pump contactor closing	2#YJH	I 14.4
73	Lubrication heater contactor closing	RJJH	I 14.5
74	Hydraulic heater contactor closing	YJJH	I 14.6
75	Select No. 1 hydraulic pump	X1#Y	I 15.0
76	Select No.2 hydraulic pump	X2#Y	I 15.1
77	Select No. 1 lubrication pump	X1#R	I 15.2
78	Select No. 2 lubrication pump	X2#R	I 15.3
79	High voltage cabinet tripping fault	GGZG	I 16.0
80	Backup 1	BY-1	I 16.1
81	Backup 2	BY-2	I 16.2
82	Centrifugal switch	LXK	I 16.3
83	Loose rope	SS	I 16.4
84	Backup 3	BY-3	I 16.5
85	Signal emergency stop	XHJT	I 16.6
86	Hydraulic station pressure too high	YYG	I 16.7

87	Closing of No.1 High Voltage incoming cabinet	GYJ-1	I 17.0
88	Closing of No.2 High Voltage incoming cabinet	GYJ-2	I 17.1
89	Closing of feeder cabinet	KDH	I 17.2
90	Backup 4	BY-4	I 17.3
91	Light fault of high voltage cabinet	GGQG	I 17.4
92	Backup 5	BY-5	I 17.5
93	Brake shoe wear	ZM	I 17.6
94	Spring fatigue	THPL	I 17.7
95	Wellhead deceleration	JKJ	I 18.0
96	Bottom hole deceleration	JDJ	I 18.1
97	Wellhead synchronization	JKT	I 18.2
98	Bottom hole synchronization	JDT	I 18.3
99	Wellhead speed limit	JKX	I 18.4
100	Bottom hole speed limit	JDX	I 18.5
101	Wellhead shutdown	JKTC	I 18.6
102	Bottom hole shutdown	JDTC	I 18.7
103	Wellhead overwinding	JKG	I 19.0
104	Bottom hole overwinding	JDG	I 19.1
105	Wellhead limit overwinding	JKJG	I 19.2
106	Bottom hole limit overwinding	JDJG	I 19.3
107	Archway on the scroll	PSG	I 19.6
108	Archway under the scroll	PXG	I 19.7
109	High oil temperature in lubricating oil tank	RYWG	I 20.0
110	Low oil temperature in lubricating oil tank	RYWD	I 20.1
111	Low oil pressure in lubricating oil tank	RYYD	I 20.2
112	Normal lubricating oil pressure	RYZ	I 20.3
113	High oil temperature at lubricating oil outlet	RCWG	I 20.4
114	1 lubricating oil filter blocked	R-1LD	I 20.5
115	2 lubricating oil filter blocked	R-2LD	I 20.6

116	Low lubricating oil pressure	RYWG	I 20.7
117	Backup 6	BY-6	I 21.0
118	Backup 7	BY-7	I 21.1
119	1 hydraulic oil filter blocked	Y-1LD	I 21.2
120	2 hydraulic oil filter blocked	Y-2LD	I 21.3
121	Opening signal	KZX	I 21.4
122	Closing signal	BZX	I 21.5
123	Backup 8	BY-8	I 21.6
124	Backup 9	BY-9	I 21.7
125	Lifting people	XTR	I 22.0
126	Lifting object	XTW	I 22.1
127	Lowering special materials	XXT	I 22.2
128	overhaul	XJ	I 22.3
129	Slow up	XMS	I 22.4
130	Slow down	XWX	I 22.5
131	promote	XT	I 22.6
132	Go down	XX	I 22.7
133	Start up signal	KX	I 23.0
134	Stop signal	TX	I 23.1
135	No.1 broken shaft protection	DZ-1	I 23.2
136	No.2 broken shaft protection	DZ-2	I 23.3
137	Archway deceleration switch	PJK	I 23.4
138	Backup	BY-10	I 23.5
139	Speed limit switch on archway	PSXK	I 23.6
140	Speed limit switch under archway	PXXK	I 23.7

Table 7 DO module configuration

Serial number	Annotation	Symbolic name	Address
1	Feeder cabinet closed	KDGH	Q 0.0
2	Feeder cabinet open	KDGF	Q 0.1
3	Backup 1	BYQ-1	Q 0.2
4	Backup 2	BYQ-2	Q 0.3

5	Backup 3	BYQ-3	Q 0.4
6	Backup 4	BYQ-4	Q 0.5
7	Lubrication heater control	RJK	Q 0.6
8	Hydraulic heater control	YJK	Q 0.7
9	Main fan control	ZFK	Q 1.0
10	Lubrication station No. 1 control	1#RK	Q 1.1
11	Lubrication station No. 2 control	2#RK	Q 1.2
12	Hydraulic station control	YK	Q 1.3
13	G5 control	G5K	Q 1.4
14	G6 control	G6K	Q 1.5
15	Down long material interlock 1	XCL1	Q 1.6
16	Down long material interlock 2	XCL2	Q 1.7
17	High-voltage closing light	GYHD	Q 12.1
18	Inverter ready light	BJD	Q 12.2
19	Inverter running light	BYD	Q 12.3
20	Hydraulic station working light	YGGD	Q 12.4
21	Lubrication station working light	RGGD	Q 12.5
22	Main fan running light	ZYD	Q 12.6
23	Operation allowed light	YKD	Q 12.7
24	Operation signal light	KXD	Q 13.0
25	Rope loosening indicator light	SS-LED	Q 13.1
26	Lifting light	TSD	Q 13.2
27	Lowering light	XFD	Q 13.3
28	Overwinding reset light	GFD	Q 13.4
29	Deceleration light	JSD	Q 13.5
30	Secondary brake release light	EZJD	Q 13.6
31	Rope adjustment light	TS-D	Q 13.7
32	Test mode light	SFD	Q 14.2
33	Backup	QBY-6	Q14.3
34	Encoder No. 1 fault	BMQGZ1-LED	Q 14.4

35	Encoder No. 2 fault	BMQGZ2-LED	Q 14.5
36	Inspection light	JXD	Q 14.6
37	Handle zero position light	SBLD	Q 14.7
38	Software safety circuit light	RAHD	Q 15.0
39	High-voltage cabinet fault light	GG-LED	Q 15.1
40	Inverter fault ligh	B-LED	Q 15.2
41	Hydraulic station heating light	YJD	Q 15.3
42	Hydraulic station fault light	YGD	Q 15.4
43	Lubrication station fault light	RGD	Q 15.5
44	Equal speed overspeed light	DSGD	Q 15.6
45	Wrong direction protection light	CXD	Q 15.7
46	Speed measurement fault light	CGD	Q 16.0
47	Deceleration overspeed light	JGD	Q 16.1
48	Fixed point overspeed light	DGGD	Q 16.2
49	Working brake fault light	GGD	Q 16.3
50	Slipping protection light	LCBD	Q 16.4
51	Comprehensive upper overwinding light	ZSD	Q 16.5
52	Comprehensive lower overwinding light	ZXG	Q16.6
53	Emergency parking light	JJTD	Q16.7
54	Minor fault light	QGD	Q 17.0
55	In-place parking light	DWTD	Q 17.1
56	Lifting people light	TR-LED	Q 17.2
57	Lifting object light	TW-LED	Q 17.3
58	Brake shoe wear light	ZWMS-LED	Q 17.4
59	Inspection light	JXD	Q 17.5
60	Lubrication station heating light	RJ-LED	Q 17.6
61	Buzzer	FMQ	Q 17.7

Table 8 AO module configuration

Serial number	Signal name	Symbolic name
1	Inverter frequency	BPQPL
2	Brake handle given	ZDSG

Table 9 AI module configuration

Serial number	Signal name	Symbolic name
1	Motor voltage	DJDY
2	Motor current	DJDL
3	Hydraulic station oil pressure	YYY
4	Lubrication station oil pressure	RYY
5	Brake handle	ZDS
6	Master handle	ZLS

4.2.1 Overview of high voltage inverter

High voltage AC motor plays a vital role in industrial and mining enterprises and is the source of the initiative [38-39]. Most AC motors need speed regulation function, but in many factories and mines, the speed regulation and starting technology of motors is still lagging behind, resulting in a large amount of energy loss and a significant reduction in the life of mechanical equipment. Therefore, as the key technology to improve energy efficiency and product quality, high voltage variable frequency speed regulation technology has been widely developed. Since the 1980s, with the rapid development of high-power power electronic device manufacturing technology and the promotion of market demand, the components of high-voltage inverter have changed from SCR, GTO, GTR to IGBT and IGCT, and the power required for its operation has also increased significantly. The technology has achieved significant improvement and gradually matured. This makes the high-voltage variable frequency speed regulation technology win more and more attention and love in the industry.

According to the principle of electromechanics, the speed formula of AC motor is:

$$n = n_0(1-s) = \frac{60f}{p}\ （1-s）\text{(Asynchronous motor)}$$

In the equation, f refers to the system frequency, P represents the number of poles of the motor, and s represents slip.

According to equation 4-1, we can find that the speed of the asynchronous motor can be controlled by changing the frequency f of the AC power supply on the premise of keeping the pole pairs P and slip s of the asynchronous motor constant. In other words, the function of the frequency converter is to control the speed of the motor by adjusting the frequency (for example, from 50Hz to 60Hz).

4.2.2 Structure of high voltage inverter

The structure of high voltage inverter is mainly divided into two parts: main circuit and control circuit.

The main circuit is further divided into the following four parts:

The rectifier part, also known as the grid side converter part, is used to convert three-phase AC to DC. Common low-voltage rectifying methods include uncontrollable bridge circuit composed of diodes and controllable bridge circuit composed of thyristors.

DC link. Due to the reactive power exchange between DC link and motor, energy storage components are needed to achieve energy buffering.

The inverter part, also known as the load side converter part, mainly generates three-phase AC energy by adjusting the on and off time of the switch tube in the three-phase bridge inverter circuit.

Braking or feedback link. A large amount of regenerative energy will be generated during braking, so the feedback link is required to send these energy back to the power grid to prevent the DC bus side voltage from being too high.

The control loop is composed of the following four parts:

Detect the sensing circuit. It is mainly responsible for sampling current, voltage, speed, temperature and other parameters.

Control signal input/output circuit. It usually includes input multi-function selection terminal, positive and negative rotation terminal and reset terminal; Relay outlet terminal and open collector outlet multifunctional terminal; The analog input terminal is used for external analog signal power supply and setting analog voltage and current frequency; The analog output terminal is used to output the analog quantity of frequency and current.

Drive circuit. It mainly includes fan drive circuit, contactor drive circuit and six PWM output drive circuit.

Protection circuit. It mainly includes residual voltage detection circuit, phase failure detection circuit, etc.

4.2.3 Selection of high voltage inverter

According to the upgrading plan of electric control system in Baidong mine, the economy, practicability and convenience of maintenance were comprehensively evaluated, and the jd-bp37/38 series high-voltage inverter manufactured by Shandong Xinfeng Electronic Technology Co., Ltd. was finally adopted. This series of frequency converters has the following outstanding characteristics:

It adopts advanced space voltage vector control technology, carrier phase shift control technology and "runaway start" technology;

With instant power failure restart function, the equipment can still maintain normal operation even if the control power supply is interrupted;

It provides a comprehensive function of frequency converter parameter setting;

Its power circuit is designed as modular integration, easy to maintain, and has excellent interchangeability;

Equipped with touch screen Chinese operation interface;

The PLC interface board is designed to adjust the control logic according to different production requirements;

The communication between the main loop and the controller is realized through optical fiber, which effectively reduces the interference and enhances the stability of the system;

It has comprehensive fault monitoring function, provides accurate fault protection, and accurate fault location display and alarm;

The input power factor is high and the harmonic content is low, so there is no need to install additional compensation equipment;

As a high-high voltage source inverter, when the input voltage is 6kV or 10kV, the output voltage also remains 6kV or 10kV;

It can receive and transmit multiple 4~20mA industrial standard signals at the same time, which is convenient for interfacing with the user's DCS system;

Support modbus, PROFIBUS and other communication protocols;

The output is a stepped sinusoidal PWM waveform, which can effectively reduce the damage to the device in the transmission process without additional compensation and filtering equipment;

Figure 27: Physical drawing of filter equipment

According to the transformation scheme of electric control system in Baidong mine, taking into account the economic, practical, convenient maintenance and other factors, jd-bp37/38 series high-voltage inverter produced by Shandong Xinfeng Electronic Technology Co., Ltd. was selected. This series of frequency converters has the following characteristics:

Advanced space voltage vector control technology, carrier phase shift control technology and "runaway start" technology are adopted;

With instant power failure restart function, even if the control power supply is powered down, it can still maintain normal operation;

Provide perfect frequency converter parameter setting function;

The power circuit is designed as an integrated module, which is convenient for maintenance and has good interchangeability;

Equipped with touch screen Chinese operation interface;

PLC interface board is designed to adjust the control logic according to different

production requirements;

The communication between the main loop and the controller is realized through optical fiber, which can effectively reduce interference and improve system reliability;

It has perfect fault monitoring function, provides accurate fault protection, and accurate fault location display and alarm;

The input power factor is high and the harmonic content is less, so there is no need to add additional compensation equipment;

As a high-high voltage source inverter, when the input voltage is 6kV or 10kV, the output voltage is also 6kV or 10kV;

It can acquire and transmit multiple 4~20mA industrial standard signals at the same time, which is convenient for interfacing with the user's DCS system;

Users can choose modbus, PROFIBUS and other communication protocols;

The output is a stepped sinusoidal PWM waveform, which can reduce the damage to the device in the transmission process without additional compensation and filtering equipment.

In addition to the above characteristics, jd-bp37/38 series high-voltage variable frequency speed regulation system also has the advantages of high cost performance, simple installation, setting and debugging. Moreover, the product is also a national Torch Program project, and the technical level is leading in China. The outline drawing of the whole variable frequency speed regulation system is shown in Figure 27. Its main components are:

Switching cabinet/wiring cabinet: when the fault occurs, the switching cabinet acts to switch the motor to the power frequency grid, and the wiring cabinet is used to connect the input and output of the frequency converter.

Transformer cabinet: place phase-shifting rectifier transformer to provide power input for equipment.

Power cabinet: it mainly provides output voltage for the motor after speed regulation change.

Control cabinet: it is mainly used to control the variable frequency speed regulation system, process data information and realize the communication function. Jd-bp37-560t high voltage variable frequency speed regulation system is finally selected according to the motor parameters of the main shaft of Baidong mine.

4.2.4 Working principle of high voltage inverter

Jd-bp37-560t high voltage variable frequency speed regulation system is composed of phase-shifting transformer, power unit and controller. This model contains 15 power units, and each of them is connected in series to form a phase. Figure 28 shows the structure of jd-bp37-560t high voltage variable frequency speed regulation system.

(1) Power unit. The circuit structure is shown in Figure 29, which adopts the basic AC-DC-AC single-phase inverter circuit design. Six diodes are used at the rectifier side to realize three-phase full wave rectification, and the required AC is output by controlling IGBT. Each power unit on the inverter side has the same structure and is interchangeable, which greatly facilitates the debugging and maintenance work.

The input side supplies power to each power unit through a phase-shifting transformer. Each power unit is responsible for all motor current, 1/5 phase voltage and 1/15 output power. The secondary winding adopts the extended triangle connection method to reduce the harmonic content. The 15 secondary windings are divided into three phase groups. The number of power units will vary depending on the power and voltage levels.

The output side supplies power to the motor through the U, V and W terminals of each unit in the form of star connection. The line voltage waveform as shown in Figure 30 can be obtained through the reorganization of the unit PWM waveform. The waveform has high sinusoidal degree and low voltage change rate, which effectively reduces the damage to transmission devices. At the same time, due to the less harmonic content, the reactive power loss of the motor is reduced, and the mechanical vibration is also significantly reduced, thus reducing the wear of the equipment.

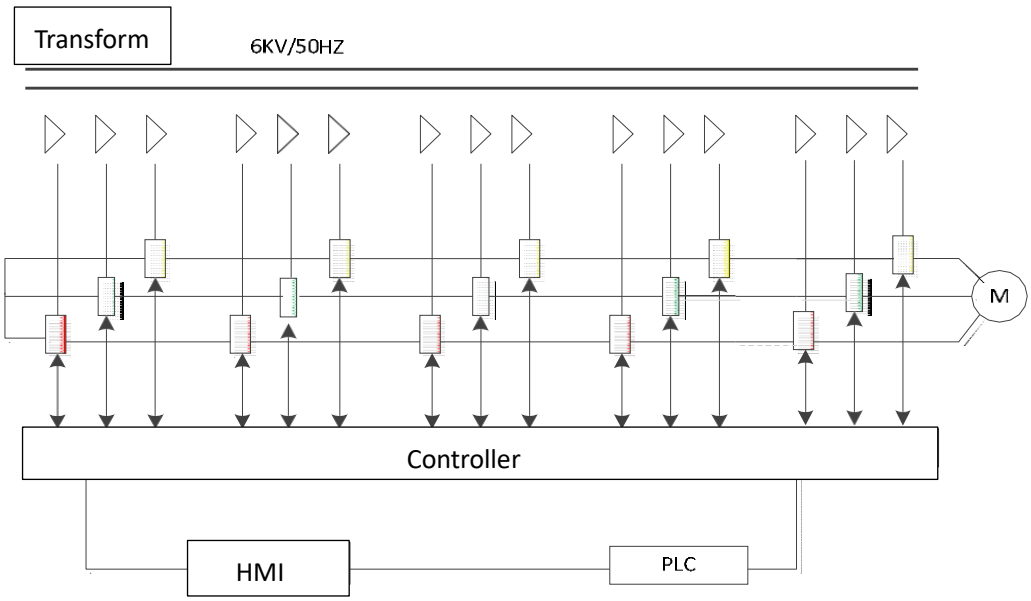

Figure 28: Structure diagram of high voltage variable frequency speed regulation system

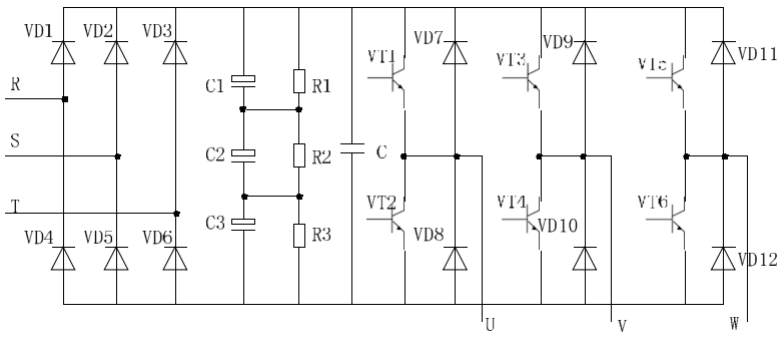

Figure 29:Power unit circuit structure

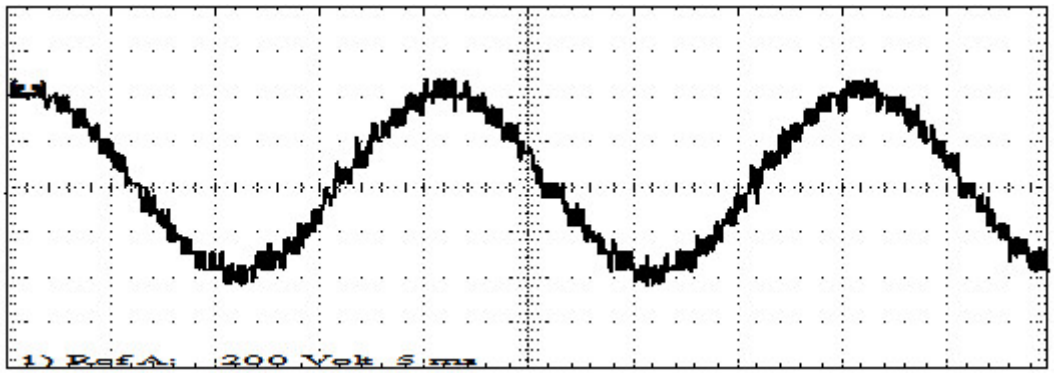

Figure 30: Line voltage waveform

(2) Control device. As shown in Figure 31, the circuit board layout inside the control box is motherboard, main control board, conditioning board, and fiber board, arranged from left to right. The core of the control device is composed of a high-speed 32-bit DSP and a human-machine interface. The designed algorithm ensures that the motor runs in the best state. The device is equipped with a Chinese control interface, which greatly facilitates the

operator's control and abnormal monitoring of the equipment. Using the PLC control device, we processed the switch signal in the switch cabinet and optimized and amplified the status signal and control signal to achieve system coordination and flexibility. Between the control device and the power unit, we selected optical fiber as the transmission medium to achieve effective isolation of the high and low voltage parts, which not only improves the accuracy of the system, but also effectively avoids electromagnetic interference. In addition, the system also integrates a third harmonic compensation device to optimize the system voltage so that the utilization rate of the power supply voltage is close to 100%. By applying phase-shift carrier technology to the system, we achieve the addition of the fundamental wave and the subtraction of the harmonics, so that the output waveform is closer to the real waveform.

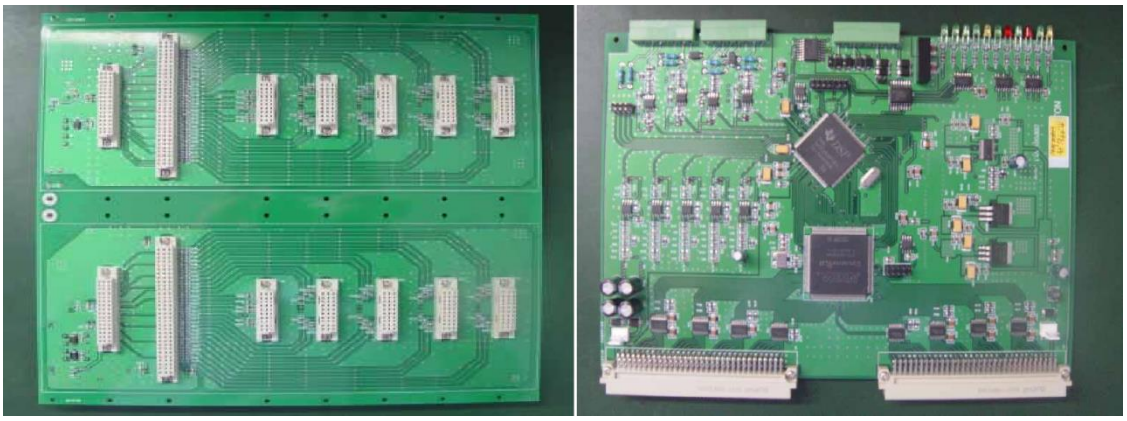

Figure 31: Physical drawing of control box circuit board

4.3 Summary of this chapter

In this chapter, the hardware composition of the electric control system is discussed in depth. According to the requirements of the electric control system of Baidong mine hoist, S7-300 series PLC developed by Siemens is selected. In this paper, the configuration scheme of the main control PLC in Baidong mine is described in detail, and the I/O interface is reasonably allocated according to the actual needs of the site. In terms of speed regulation system, this chapter introduces the structure of high-voltage inverter, and finally selects jd-bp37/38 series high-voltage inverter manufactured by Shandong Xinfeng Electronic Technology Co., Ltd., and summarizes its operation principle.

5 Software design of mechanical and electrical control system

The software design of electric control system includes two main parts: PLC program design and upper computer software design. Among them, the PLC program design is further subdivided into two aspects: the main program design and the function block program design, while the upper computer software design is mainly focused on the development of touch screen monitoring software program.

5.1 Introduction to programming software STEP7

STEP7 is applicable to SIMATIC S7, C7 and M7 series. It is a software integrating programming, monitoring and parameter setting [40]. It supports flexible configuration of hardware, free setting of parameters, network configuration and construction of communication structure, and can perform many functions such as program programming, testing, maintenance and diagnosis.

The programming functions of STEP7 mainly include:

Programming language: it supports three basic programming languages: ladder diagram, statement table and function block diagram [41]. At the same time, users can directly use advanced programming languages such as s7-scl (structured control language), s7-graph (sequential function diagram language), s7higraph and CFC (continuous function diagram).

Symbol table editor: allows users to edit and search the address of internal components symbolically.

Test and service functions: users can set breakpoints, force input and output, rewire, display cross reference tables, use status functions, and monitor the status of multiple program blocks at the same time. A specific point in the program can be quickly located by entering a symbol name or address.

Help function: during programming, the user can press F1 to obtain relevant help information, or click "help (H)" → "content (c)" in the menu bar to enter the help window.

5.2 Hardware configuration and network configuration

To start the installed STEP7 software, the first interface is to create a program project. The project is named "Baidong mine main shaft high voltage frequency conversion program". Right click the item and insert two simatic300 stations inside it to form a dual redundant structure, as shown in Figure 32. Each site represents the hardware structure of the PLC, through which you can view the configuration, address, status and other details of each module.

Taking simatic300 (1) station as an example, the hardware of the station is edited according to the requirements with reference to the description of PLC hardware composition in Baidong mine in Chapter III. The specific operation steps are to click the site, and then edit the hardware in the site. First select the guide rail to insert each module. According to the PLC hardware configuration described in section 4.1.2, find each module in turn, and drag it from the right configuration file to the guide rail. The configuration of the master station of the master control system is shown in Figure 33, and the configuration of the slave station et200 (im153) is shown in Figure 34. The Profibus Technology can be used for network configuration. The hardware configuration of the whole system is shown in Figure 35.

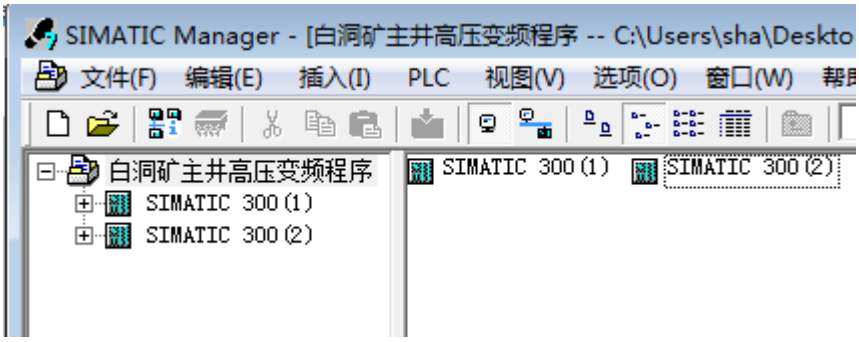

Figure 32: Project Creation

(0) UR

插...	模块 ...	订货号 ...	固件	MPI 地址	I 地址	Q 地址	注释
1	PS 307 5A	6ES7 307-1EA00-0AA0					
2	**CPU 314C-2 DP**	**6ES7 314-6CG03-0AB0**	**V2.6**	**2**			
X2	*DP*				*1023**		
2.2	*DI24/DO16*				*124...126*	*124...125*	
2.3	*AI5/AO2*				*752...761*	*752...755*	
2.4	*计数*				*768...783*	*768...783*	
2.5	*定位*				*784...799*	*784...799*	
3							
4	AI8x12Bit	6ES7 331-7KF02-0AB0			256...271		
5	DI32xDC24V	6ES7 321-1BL00-0AA0			4...7		
6	DI32xDC24V	6ES7 321-1BL00-0AA0			8...11		
7	DO32xDC24V/0.5A	6ES7 322-1BL00-0AA0				12...15	
8	DO32xDC24V/0.5A	6ES7 322-1BL00-0AA0				16...19	
9	AO4x12Bit	6ES7 332-5HD01-0AB0				336...343	

Figure 33: Master station configuration

(3) IM 153-2

插...	模块 ...	订货号 ...	I ...	Q ...	注释
1					
2	*IM 153-1*	*6ES7 153-1AA03-0XB0*	*1017**		
3					
4	DI32xDC24V	6ES7 321-1BL00-0AA0	0...3		
5	DI32xDC24V	6ES7 321-1BL00-0AA0	12...15		
6	DI32xDC24V	6ES7 321-1BL00-0AA0	16...19		
7	DI32xDC24V	6ES7 321-1BL00-0AA0	20...23		
8	DO32xDC24V/0.5A	6ES7 322-1BL00-0AA0		0...3	
9					

Figure 34: Slave configuration

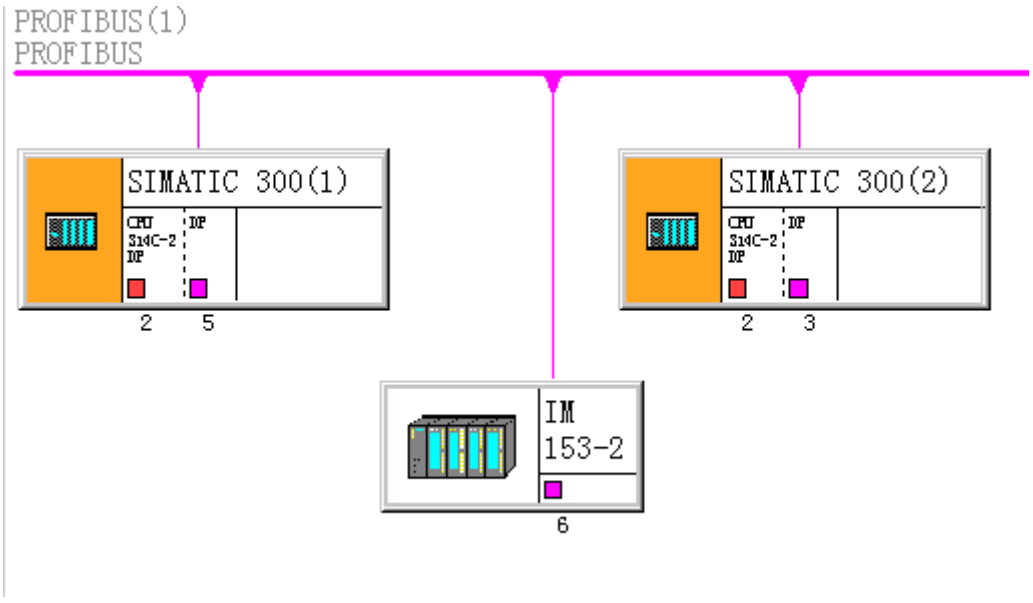

Figure 35: System hardware network configuration

5.3 PLC program design

The operating system and user program together constitute the core of PLC program. The operating system is usually responsible for processing tasks unrelated to control requirements, such as interrupt processing, error management, storage area management, and communication processing. The user program can be directly generated in the software and loaded into the CPU through a dedicated data line to achieve specific control functions.

In order to facilitate the search, modification and debugging of the program, the STEP7 program design adopts the block structure. The blocks in the user program mainly include organization block (OB), system function block (SFB), system function block (SFC), function block (FB), function block (FC), background data block (DI) and shared data block (DB). The functions of each block are briefly described below:

Organization block (OB): it is responsible for docking the program written by the user with the operating system and determining the structure of the user program.

System function block (SFB): plays a role when key system modules need to be called.

System function (SFC): its function is the same as that of SFB. The difference is that SFC does not have its own storage area, while SFB has a storage area.

Function block (FB): a user-defined function subroutine.

Function (FC): its function is the same as that of FB. The difference is that FC has no storage area, while FB has storage area.

Background data block (DI): the data block used to pass parameters when calling FB and SFB.

Shared data block (DB): used to store user data and provide data sharing function.

A complete program can be composed of these different types of blocks. The organization block ob can call FC, FB, SFB, SFC, and FC or FB can also call other FC or FB through the nested structure. It should be noted that when using FB and SFB, corresponding background data blocks must be provided.

The flow chart of system design is shown in Figure 36.

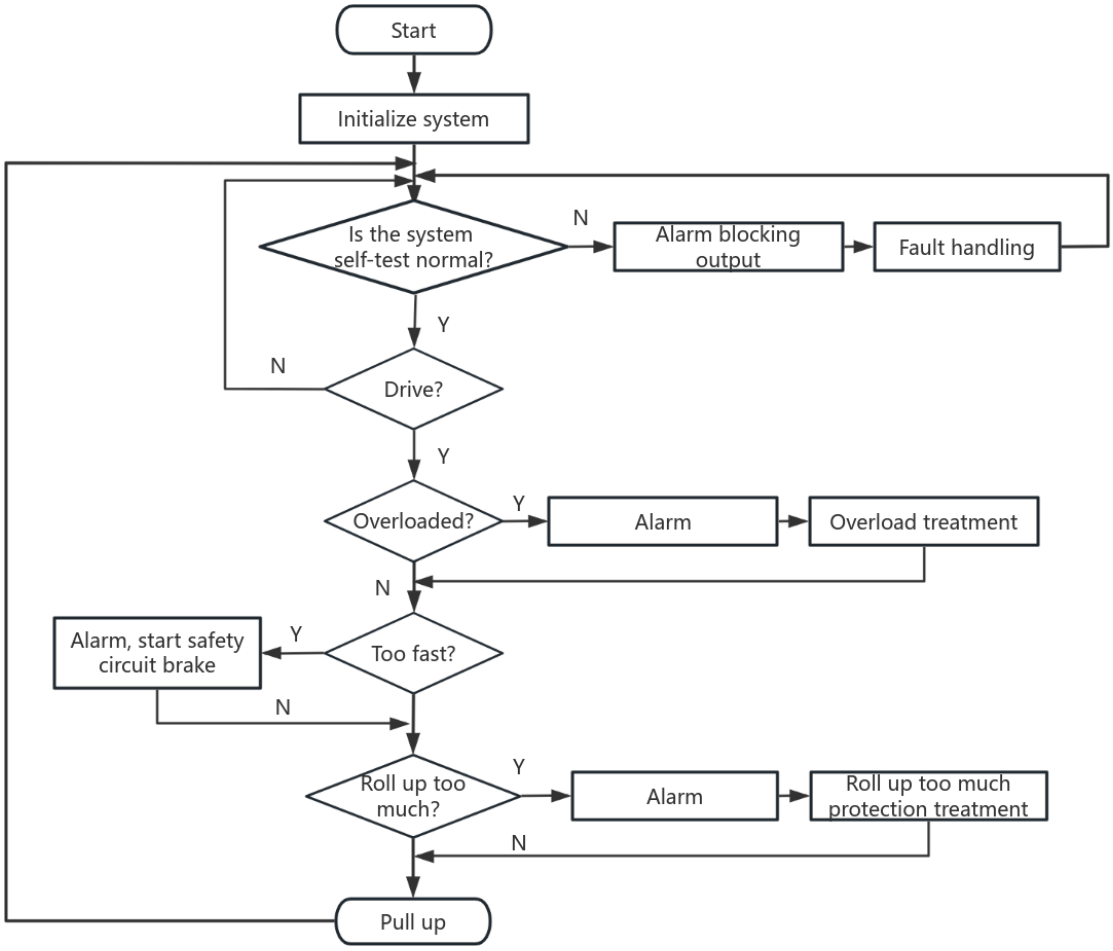

Figure 36: System flow diagram

According to the flowchart, the block shown in Figure 37 was written in CPU 314C-2DP.

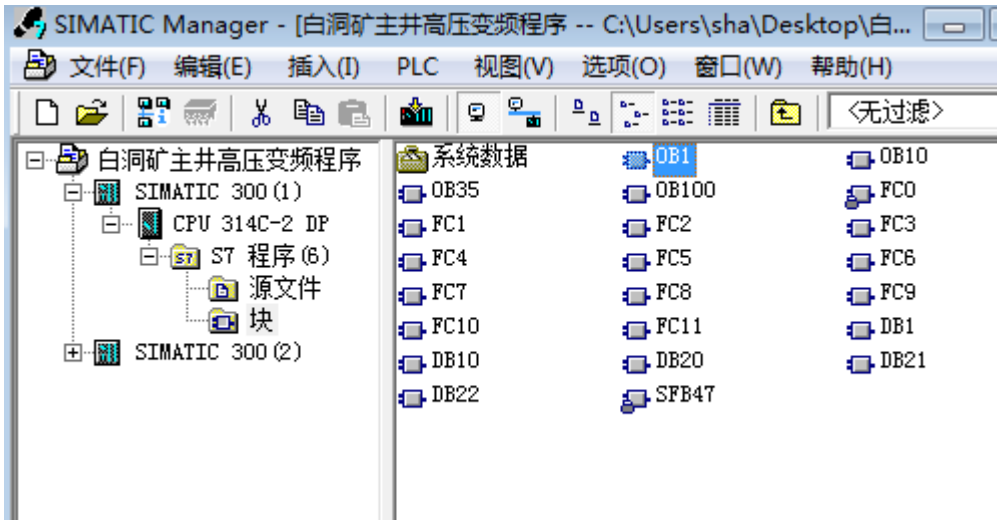

Figure 37: Program block

The main program module ob1 is mainly responsible for the initialization of the system

and calling the required Fc function modules. As shown in Figure 38, the system first performs initialization, and then calls FC5 to read encoder data and perform depth calculation. Next, the system calls FC4 to check the encoder settings, and then FC2 to review the security module. After that, the system checks the configuration of auxiliary circuit and commutation circuit by calling FC3. Subsequently, the system calls FC6 to control the lifting speed, and then calls fc7 to process analog data. The system then performs encoder travel protection by calling fc8. Finally, the system calls fc9 and FC10 to control the adjustable gate.

```
OB1 :"Main Program Sweep  (Cycle)"
程序段 1：标题：
    O      M 0.0
    ON     M 0.0
    =      M 0.0
程序段 2：标题：
   CALL   "READ-FM350"          FC5    --读编码器，深度计算
   CALL   "DX-BMQSZ"            FC4    --编码器设置
   CALL   "AC-CIRCUIT"          FC2    --安全保护
   CALL   "RELAY-CIRCUIT"       FC3    --辅助回路、换向回路
   CALL   "V-RELAY-CIRCUIT"     FC6    --速度回路
   CALL   "AI-READ"             FC7    --模拟量输入
   CALL   "SOFT-RELAY"          FC8    --编码器行程保护
   CALL   "SOFT-VG"             FC9    --可调闸闭环
   CALL   "AO-OUT"              FC10   --可调闸输出
```

Figure 38: System main program

5.3.1 Introduction to safety protection module

FC2 is a safety protection module. During the operation of the hoist, various faults will inevitably be encountered. The module carries out software safety protection design for possible faults, such as frequency converter fault, over speed fault (including constant speed, deceleration, 2-meter speed limit), spring fatigue fault, over winding fault (including upper over winding and lower over winding), high voltage cabinet trip fault, etc. The flow chart of the module program design is shown in Figure 39. The following is a brief introduction to the common overwinding faults of the hoist.

The over roll protection procedure is shown in Figure 40. There are three sources that cause the system to send the overwind fault signal, namely:

There is a deviation between the depth collected by the encoder and the set parking position.

The overwind travel switch at the wellhead or bottom of the well is touched by the lifting container.

The overwind travel switch on the memorial archway depth indicator was touched by a bumper.

As long as any of the three conditions is met, the over winding fault protection will be triggered and the hoist will immediately stop with the brake.

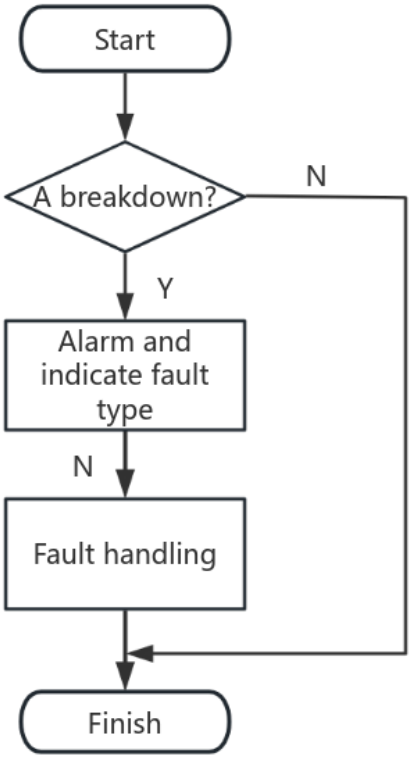

Figure 39: Flow chart of safety protection module

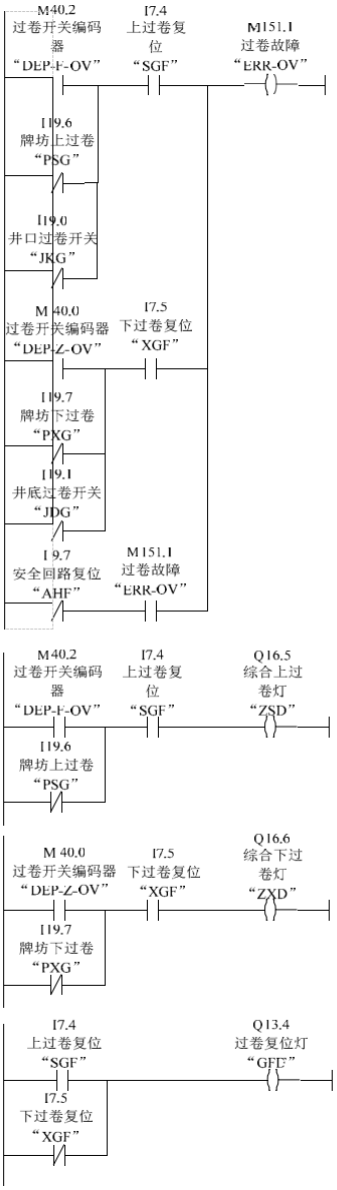

Figure 40: Over roll protection procedure

For the above failures, software safety circuit and auxiliary safety circuit must be designed to ensure that the system can immediately cut off the safety circuit and execute emergency braking in case of failure, so as to ensure the soft safety circuit of the lifting safety system, as shown in Figure 41.

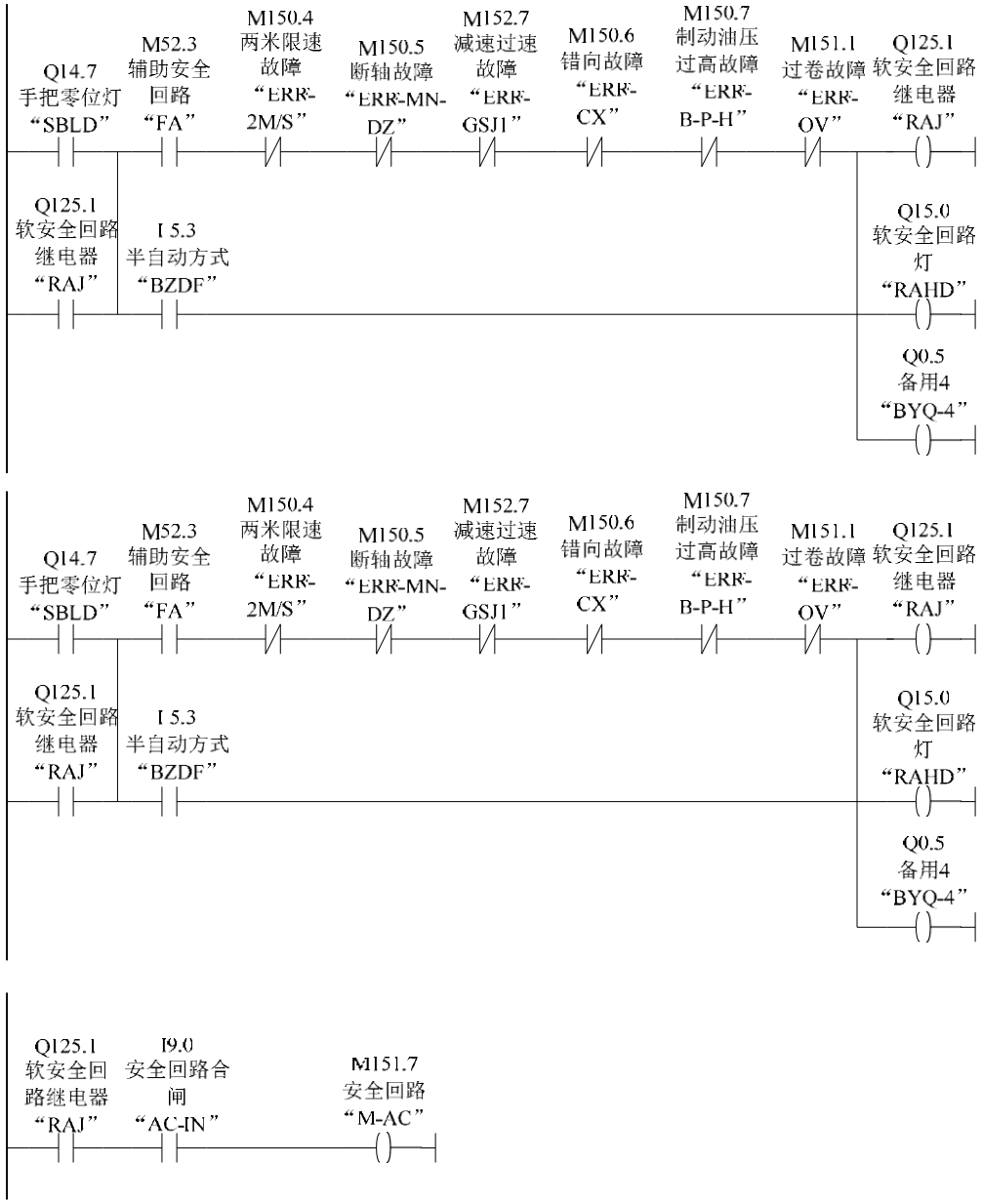

Figure 41: Soft safety loop procedure

5.3.2 Introduction to analog processing module

FC7 module is responsible for analog quantity processing. The main function of this module is to process all analog signals in the system and convert these signals into digital signals for further processing and analysis by CPU. These analog signals include the set value of the system working gate, the master set value, the current set value of the frequency converter, the current set value of the motor, the frequency set value of the frequency converter, the oil pressure set value of the hydraulic station, the oil pressure set value of the

lubrication station and the speed measurement feedback. The workflow diagram of the module is shown in Figure 42. Taking the speed measurement feedback signal processing as an example, Figure 43 shows the specific processing procedure of the speed measurement feedback signal.

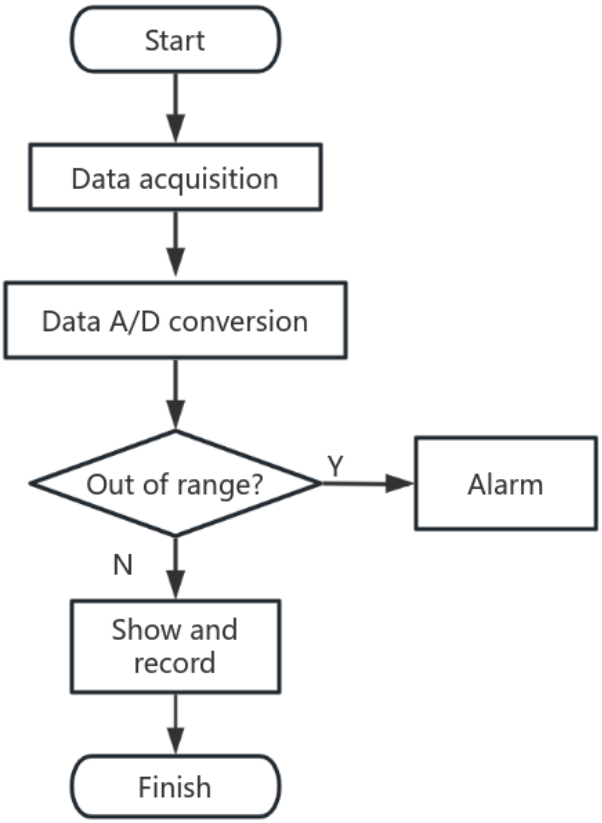

Figure 42: Flow chart of analog processing module

```
程序段 10：标题：
    L    PIW 260
    T    “db10”.AI_SP_FB_IN    DB10.DBW46  --测速反馈输入（字）
    NOP   0
程序段 11：标题：
    L    “db10”.AI_SP_FB_IN    DB10.DBW46  --测速反馈输入（字）
    ITD
    L    L#10000
    *D
    L    L#27648
    /D
    T    MD  136
    DTR
    ABS
    RND
    T    MD  140
    DTR
    L    2.777778e+001
    /R
    RND
```

Figure 43:Speed measurement feedback signal processing program

5.4 Upper computer program design

Human machine interface (HMI) is the medium and dialogue interface for transferring and exchanging information between people and computers. According to the requirements of the electric control design of Baidong mine, appropriate upper computer monitoring software must be set to realize human-computer interaction, and the data of the hoist in the working process can be monitored. These data mainly include the status and parameters of the hoist. Through the detection and recording of these data, the faults can be found in time and the operator can be reminded by sending an alarm to ensure the safety of mine production.

Baidong mine uses the touch screen produced by Huainan wanwei electromechanical Co., Ltd. to realize human-computer interaction. The model of touch screen used is kc01 series. This series of touch screen configuration software exibl can be used to set the touch screen and connect with the main control PLC to realize the human-computer interaction function. The following points should be paid attention to when realizing the communication of human-computer interaction settings:

When selecting equipment type, Siemens s7-300mpi should be selected;

The serial port connection mode should be set to RS485;

The baud rate needs to be the same as that of the master plc314c-2dp, both of which are 19200bps. When the system is in initialization, the main screen of the touch screen is shown in Figure 45. The picture includes the main fan, hydraulic station

The working condition of the lubrication station and other data to be monitored, such as the voltage of the hydraulic proportional valve, the current of the frequency converter, the number of lifting hooks, etc. in addition, the speed of the hoist will be dynamically displayed in real time during actual operation. In the middle of the main screen is the speed chart of the hoist. In actual operation, the speed chart is similar to the ideal "s" type skip lifting speed chart mentioned in Section 3.1. And the specific depth and position of the hoist underground can also be indicated in real time through the depth indicator in the main interface. The touch screen also contains an interface viewing system for parameter setting, fault screen, safety loop, alarm record, hoist parameters, and historical speed chart, which can be clicked to view the working conditions of each interface. The following is a brief introduction of the safety loop interface and fault screen interface as an example.

Human machine interface (HMI), as a bridge for information transmission and communication between human and computer, is a key component of dialogue interface. According to the strict requirements of electric control design in Baidong mine, appropriate monitoring software of upper computer must be configured to achieve efficient human-computer interaction. The software needs to be able to monitor the data of the hoist in the working process in real time, which covers the key information such as the operating status and parameters of the hoist. Through the real-time detection and recording of these data, potential faults can be found in time, and the operator can be reminded through the alarm system, so as to ensure the continuity and safety of mine production.

Baidong mine selected the kc01 series touch screen produced by Huainan wanwei electromechanical Co., Ltd. to achieve efficient human-computer interaction. This series of touch screens are set by exibl configuration software and connected with the main control PLC to complete the human-computer interaction function. During human-computer interaction setting and communication, special attention shall be paid to the following points:

When selecting equipment type, Siemens s7-300mpi must be selected;

The serial port connection mode shall be set as RS485;

The baud rate shall be consistent with that of the master plc314c-2dp, which is 19200bps. When the system is initialized, the main screen of the touch screen is shown in Figure 44. The screen shows the working conditions of main fan, hydraulic station, lubrication station and other key monitoring data, such as hydraulic proportional valve voltage, frequency converter current, lifting hooks, etc. The speed of the hoist will be dynamically displayed in real time during actual operation. In the center of the main screen is the hoist speed diagram, whose operation state is similar to the ideal "s" type skip hoisting speed diagram described in Section 3.1. In addition, the specific depth and position of the hoist underground can also be displayed in real time through the depth indicator in the main interface. The touch screen also includes the interface viewing system of parameter setting, fault screen, safety circuit, alarm record, hoist parameters and historical speed chart. Users can click to enter to view the working conditions of each interface. Next, we will briefly introduce the safety loop interface and fault screen interface as examples.

Figure 44:Touch screen main interface

By clicking the "safety loop" option on the touch screen, the user can monitor the status of the safety loop in real time. Once the system fails, the interface will allow the user to quickly identify the specific fault point and fault type, so that the maintenance personnel can

accurately locate and repair the problem. The safety loop interface of the touch screen is shown in Figure 45.

When the system detects abnormal operation, the user can click the fault screen to view the fault details, and the relevant interface is shown in Figure 46. In addition, when the fault occurs, the touch screen will automatically record the fault information to the alarm record, which is convenient for the shift driver to query. These alarm records can be saved in the touch screen for up to three months, and can also be exported through SD card or USB flash disk for archiving as permanent historical data.

Figure 45:Safety loop interface

Figure 46:Fault screen interface

5.5 Summary of this chapter

This chapter focuses on how to improve the software performance of the hoist electronic control system, and discusses in detail the application of PLC programming software, the optimization of system configuration, and the construction of network configuration. Based on the electric control flow chart of the hoist system, this chapter designs the corresponding PLC control program, and explains and expounds the selected program paragraphs in detail. On the basis of completing the PLC program design, this chapter further starts to design the monitoring software of the upper computer. Through the communication with PLC, the intuitive human-computer interaction interface is created by using the world wide touch screen, so as to realize the effective monitoring of the upper computer.

6 System Debugging

6.1 Debugging Content

The commissioning of the electronic control system is an indispensable and critical step before operation, through which potential problems with the system software or hardware can be identified to ensure that the system is correct and thus allowed to be put into use in the mine. The debugging of this electronic control system mainly covers two core parts: electrical interlocking test and safety protection test.

Electrical interlocking refers to the mechanism of mutual restriction between electrical equipment. The electrical interlocking test of the electronic control system includes zero position of the handle and safety circuit interlocking, starting circuit and starting signal interlocking, emergency stop and safety circuit interlocking, starting direction and over-winding direction interlocking, deceleration interlocking, rope interlocking, starting circuit and hydraulic station fault interlocking, oil pump and safety circuit interlocking, gate control interlocking, secondary safety brake interlocking, brake clearance interlocking, starting circuit interlocking Lubrication station fault interlock and other links.

The safety protection test is designed to ensure that the relevant protection measures can be effectively activated in the event of various failures during the lifting operation. The safety protection test of hoisting electromechanical control system includes over-winding protection, constant speed overspeed protection, deceleration limit protection, wrong direction protection, loose rope protection, high oil pressure protection of hydraulic station, transmission coefficient fault protection, speed difference protection, etc. In view of the hoist needs to be repeatedly lifted and lowered in the operation, over-winding accidents often occur in this process, and the consequences are extremely serious. If it is light, it will cause the lifting vessel to pull down the derrick, resulting in a major stoppage accident; If it is heavy, it may cause the lifting wire rope to break, resulting in the fall of the lifting container, resulting in casualties. Especially in the double drum elevator system, when one lifting container overrolls, the other lifting container is very likely to collide with the bottom of the well, resulting in pier tank accidents. Therefore, the test bench simulation debugging procedure for overvolume protection debugging is described in detail next.

6.2 Commissioning Overvolume Protection

The electromechanical control simulation test bench shown in Figure 47 is arranged from left to right by the operating table, the main control PLC cabinet, the frequency converter, the motor, and the depth indicating device. Three travel switches are installed on the left and right sides of the depth indicator, corresponding to the control functions of slowing down, stopping and overvolume respectively. The motor drives the belt rotation through the drive of the reducer, simulates the rotation of the drum driven by the motor in the mine, and then realizes the lifting process of the skip. If the motor speed is too fast and the deceleration measures are not implemented in time, it may lead to over-winding accidents. Before starting the simulation experiment, the ready indicator lights of the fan, frequency converter, hydraulic station and lubrication station of the main control board should be on, and the two master command handles should be in the zero position before starting. After selecting the starting direction, slowly push the brake handle upward, and the master handle can be lifted or lowered (in this example, lowered) according to actual requirements. At the beginning of system startup, the

screen displayed by the touch screen is shown in Figure 48. At this time, the frequency of the inverter is 50HZ and it is in the constant speed stage. When the bump in the depth indicator reaches the deceleration point by touching the deceleration stroke switch (at minus 240 m), the system will begin to decelerate. At this time, the frequency of the inverter is reduced to 20HZ, and the system is in the deceleration stage, as shown in Figure 49. When the container reaches the stop switch, if it fails to brake effectively, the fader still moves downward, thus touching the over-coil travel switch. At this time, the over-coil protection will be triggered, the system will brake and stop immediately, the buzzer will give an alarm, and the over-coil indicator on the operating platform will turn on. As shown in Figure 50, the alarm record can be viewed through the touch screen on the main console, and the alarm record surface is shown in Figure 51.

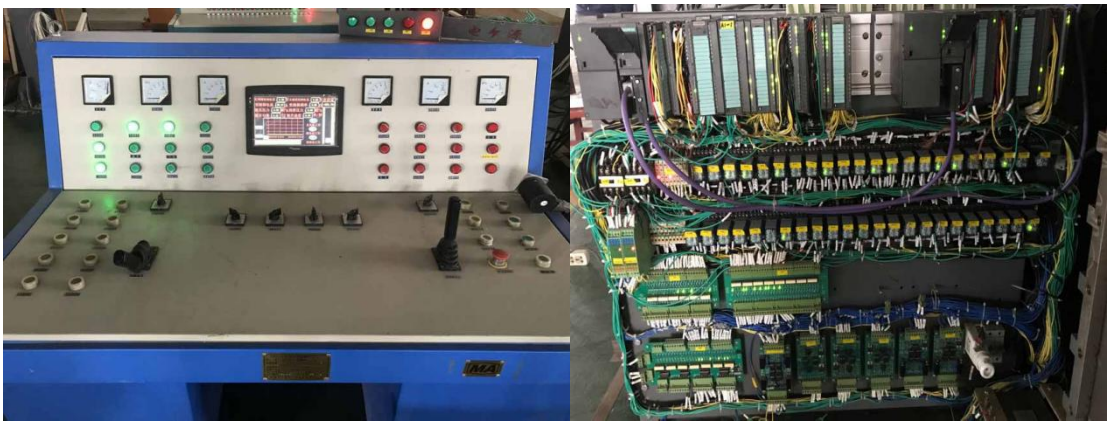

Figure 47: Simulation test bench

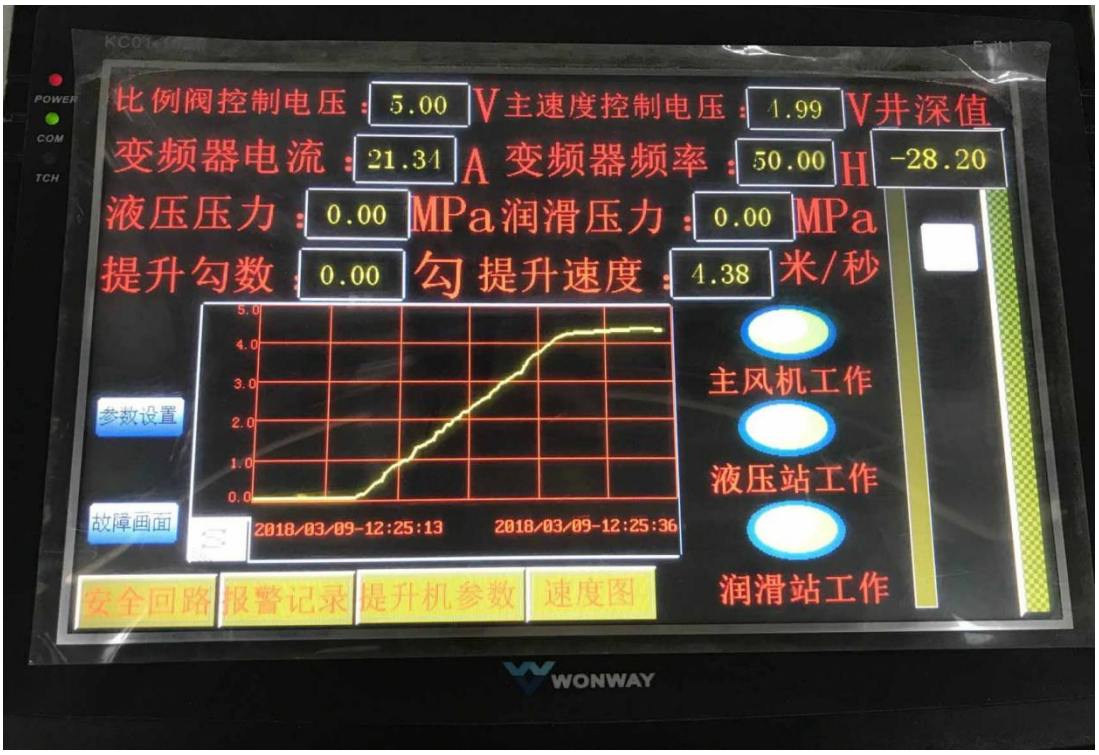

Figure 48: Initial monitoring screen

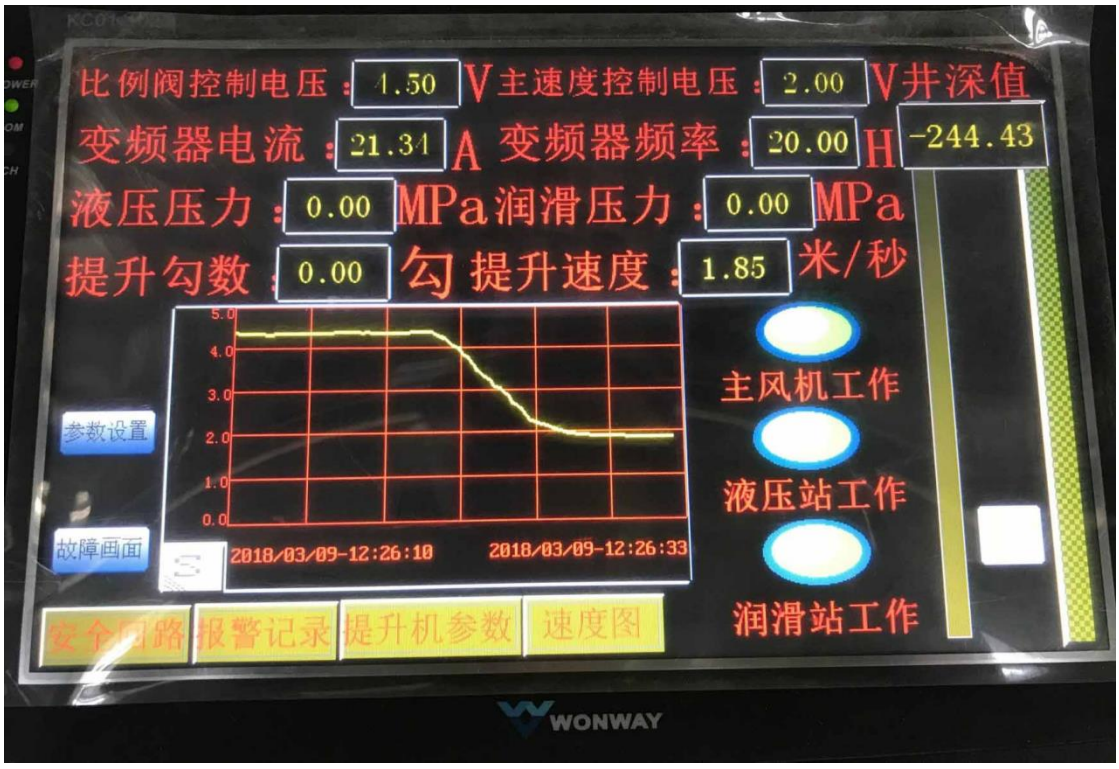

Figure 49: Deceleration point monitoring screen

Figure 50: Overvolume Test

Figure 51: Alarm record

7. Startup project

7.1 Project Background

The goal of this project is to enhance the hoist control system of Datong Coal Industry Group's Baidong Coal Mine to improve production efficiency and safety. At present, there are the following problems with the hoist control system of Baidong Coal Mine:

Lack of reliability: Traditional relay and contactor control systems are prone to malfunctions, leading to production interruptions and equipment damage.

Large maintenance workload : The system is complex, the maintenance workload is heavy, and it affects production efficiency.

High noise: The system operates with loud noise, which affects the working environment of workers.

High energy consumption: Traditional rotor series resistance speed regulation systems have low efficiency and do not comply with national energy conservation and emission reduction policies.

7.2 Project Content

The following plan will be adopted for the upgrade and renovation of the elevator control system in this project:

Adopting high reliability industrial controller PLC : Using a dual PLC control system to improve system reliability.

Adopting vector control AC-AC variable frequency speed regulation system: Improving system efficiency and speed regulation range.

Adopting fuzzy adaptive PID control algorithm to improve the accuracy and stability of hoist stroke control.

7.3 Goals and stages of implementation of the startup project

During the operation of mine hoist, the traditional control method is difficult to meet the control requirements because the controlled variables have time-varying, nonlinear, uncertain and other factors. Therefore, using dual PLC control system, vector control AC-AC Variable frequency speed regulation system, PID fuzzy algorithm controller to control the mine hoist has become an effective solution. The purpose of this chapter is to establish and prove this control system. The system is unique for its innovative use of advanced control systems, aiming to improve accuracy and reliability and surpass current market products. The innovation of the system is to make the mine hoist start more stable, with smaller overshoot, significantly reduce the response time of the system, and improve the control accuracy and reliability of the system. The launch of the project requires a detailed overview of the objectives at each stage of the development process, as shown in Table 7.3.1.

Table 7.3.1 objectives of phased implementation of control system

Stages of Control System Implementation	**Phased Implementation Goals of the Control System**
Preliminary Stage	In depth analysis of user needs and existing system defects: investigate user needs and evaluate existing system deficiencies.
Innovation and Novelty	Research and develop advanced algorithms and technologies: innovate algorithms and technologies, and surpass existing systems.
Market Analysis	Technical review and analysis of market competition: compare competitive technologies and clarify their own advantages.

Resource Allocation	Determination of resource demand: estimate material, labor and technical resources.
Financial Planning	Cost and pricing strategy: estimate the cost and formulate reasonable pricing.
Investment Phase	Fund raising: explore investment opportunities and strive for financial support.
Marketing and Sales	Sales channels and user attraction: establish sales channels, segment markets and attract users.

4 Demonstration of the relevance of the control system project and recognition of the innovation concept

The development of this control system project is based on the information and research results provided in the previous chapters, which show the limitations and deficiencies of existing control systems in similar applications. Recognizing the new demand for precision control and reliability, especially in key applications such as automation systems, this project proposes an innovative solution that is more advanced, effective and reliable than existing products.

The proposed control system stands out for its unparalleled accuracy and adaptability, which makes up for the shortcomings of the traditional system. The reflection on the problems identified in the existing system proves the necessity and feasibility of this innovative solution. Table 7.4.1 summarizes the relevance and novelty of this control system, and details its application direction and benefits to users.

Table 7.4.1 Relevance and Novelty of the Control System Project Idea

The Content of the Idea	Application Directions	Benefits for the User
Advanced Control Algorithm	Smart driving, industrial automation	Enhances accuracy and reliability, reduces operational errors, decreases system response time, and bolsters overall system reliability
Integration of Adaptive Feedback	Space Missions, High-Precision Robotics, Advanced Medical Instrumentation	Improves system adaptability to dynamic conditions, achieves higher accuracy in demanding environments
Energy-Efficient & Scalable Design	Precision Agriculture, Smart City Infrastructure	Minimizes energy consumption, adaptable to various scales and smart city needs, ensuring sustainability and efficiency

This refined table more clearly and concisely presents the relevance and novelty of the control system project idea, highlighting its key features, potential applications, and the tangible benefits it offers to users.

7.5 Analysis of the Competitive Environment

The competition of control system is dynamic and challenging. As mentioned above, there are several innovations in our system, which are the key to analyze its relative to competitors. First, compare our system with a leading market competitor, focusing on key technical and economic aspects.

Table 7.5.1 Technical and Economic Advantages

No.	**Technical and Economic Characteristics**	**Our Positioning Control System**	**Nearest Market Competitor**
1	Precision and Reliability	Advanced control provides excellent accuracy and good system reliability	Basic accuracy capability, general reliability
2	Adaptability	Strong adaptability, suitable for diversified working conditions	Limited adaptability
3	Energy Efficiency	Reduce energy consumption	Relatively high energy consumption

In order to better formulate the strategy and control this competitive space, a detailed SWOT analysis is carried out.

Table 7.5.2 Expanded SWOT Analysis

Factors	**Our Positioning Control System Assessment**
Strengths	1. Integration of cutting-edge technology ensures high precision and reliability, exceeding current industry standards. 2. Robust design concept adapts to various complex industrial scenarios and ensures stable operation in diverse environments.
Weaknesses	1. High initial development and production costs may impact market pricing and competitiveness. 2. Dependence on specific high-end components poses challenges to supply chain stability and cost control.
Opportunities	1. Growing market demand for high-performance products due to automation and precision engineering trends. 2. Potential to establish strategic partnerships with industrial giants for technological innovation and market expansion. 3. Diversification into robotics, intelligent manufacturing, and related

	fields can expand business areas and improve competitiveness. 4. Expansion of global markets, especially in emerging markets, offers more business opportunities and development space.
Threats	1. Rapid technological progress and market promotion by competitors may pose threats to market share and competitiveness. 2. Market fluctuations and changes in industry regulations may impact business strategy and market layout. 3. Competitors may launch cheaper alternatives and seize market share through price-cutting strategies.

In summary, the results of this SWOT analysis emphasize the need for the company to adopt a comprehensive and strategic approach in its development process. We should make full use of our own advantages, such as cutting-edge technology and precision that exceeds industry standards, while actively addressing weaknesses such as high costs and professional training requirements. By optimizing production processes, reducing costs, and providing user training and support, we can enhance our market competitiveness. The market expansion and cooperation opportunities with industrial giants have brought us broad development prospects, and we should seize these opportunities to promote the sustained growth of our business. However, we must also be aware of the threats posed by rapid technological change and competitive pressure, remain vigilant at all times, and continuously invest in research and innovation to ensure that the company remains invincible in the fierce market competition.

7.6 Rationality of project resource allocation

In this section, we list in detail all kinds of resources necessary for the successful implementation of the control system, including materials and capital at the material level, intelligence, human resources, intangible (such as technology, patents, etc.) and information resources at the non-material level. In particular, for the capital investment that has a decisive impact on the success of the project, we have detailed the importance and necessity of its investment in Table 7.6.1.

Table 7.6.1 Justification of Capital Investments for Mine Hoist System Improvement

(Amounts in CNY)

Articles of Capital Investment	**Amount (thousand CNY)**

Direct Material Costs	
High-reliability Industrial PLC System (Dual PLC Control)	30,000
PLC Hardware (including I/O modules, communication, etc.)	20,000
PLC Software and Licenses	5,000
Integration and Customization	5,000
Vector Control AC-AC Variable Frequency Drive System	20,000
Frequency Converter	12,000
Control Devices and Sensors	5,000
Installation and Commissioning	3,000
Fuzzy Adaptive PID Control Algorithm	5,000
Software License or Custom Development	4,000
Debugging and Optimization	4,000
Debugging and Optimization	1,000
Direct Labor Costs	
Engineering and Technical Staff	10,000
Salaries and Wages	8,000
Bonuses and Incentives	1,500
Vacation Pay and Other Benefits	500
Indirect Costs	
Training for PLC Operation and Maintenance	3,000
Technical Support and Maintenance Agreements	5,000
Safety and Environmental Compliance	2,000
Project Management and Oversight	5,000
Total Expenditures	
Production Downtime During Installation	2,000
Additional Spare Parts and Consumables	3,000
Contingency Fund for Unexpected Costs	5,000
Total Capital Investments for Mine Hoist System Improvement	85,000

Note:

(1) The amounts provided in this table are estimates and should be adjusted based on actual market prices, selected equipment specifications, and project-specific requirements.

(2) Breakdowns for each category are provided to give a more detailed understanding of the cost components.

(3) Additional costs such as taxes, transportation, and insurance may also need to be considered and added to the total investment.

This table meticulously outlines the capital investment necessary for the implementation of a positioning control system aimed at enhancing the precision of financial planning. It encompasses a wide array of project-related expenses, ranging from direct material and labor costs to more expansive expenditures tied to production management, technology advancements, and ancillary services. This all-inclusive budget serves as a vital cornerstone for strategic planning and financial stewardship of the project, ensuring that all facets of the endeavor are adequately funded and managed.

7.7 Key Activities and Key Partners

This subsection details the strategies employed to accomplish the goals outlined for the development of our project's advanced analytics platform. The essential tasks and activities are summarized in Table 7.7.1, offering a transparent breakdown of each phase in the process.

Table 7.7.1

Name of Activity	Description of Activity	Activity Result
Requirement Gathering	Collecting and analyzing stakeholder needs and expectations through interviews, surveys, and workshops.	Defined project scope, requirements, and stakeholder expectations.
Data Collection & Preprocessing	Gathering relevant data from various sources and preparing it for analysis by cleaning, formatting, and normalizing the data.	Clean, organized datasets ready for analysis and insights generation.
Technology Evaluation	Assessing and selecting the most suitable technologies and tools for the project based on factors such as cost, scalability, and ease of use.	Selected technology stack, tools, and platforms for the analytics solution.
Algorithm Development	Designing and developing advanced algorithms for data analysis, pattern recognition, and insights generation.	Developed algorithms, models, and initial test results demonstrating the platform's capabilities.
Platform Design & Architecture	Planning and designing the overall structure, architecture, and user interface of the analytics platform.	Detailed design specifications, architecture diagrams, and user interface mockups.
Development Phase	Coding and integrating the various components of the platform, including data ingestion, processing, analysis, and visualization modules.	Fully functional platform codebase with integrated components and features.
Testing & Quality Assurance	Conducting rigorous testing to ensure platform reliability, accuracy, and performance across various scenarios and datasets.	Tested and verified platform performance, reliability, and accuracy.
User Training & Documentation	Creating user manuals, tutorials, and offering training sessions for platform users to ensure they can effectively use the platform.	User-friendly documentation, trained users, and increased platform adoption.
Deployment & Integration	Setting up and integrating the platform into the client's existing systems, workflows, and data sources.	Successfully deployed and integrated platform, ready for use by the client.
Maintenance & Support	Providing ongoing maintenance, updates, and support to ensure platform	Ongoing platform support, updates, and performance

	performance, security, and reliability over time.	optimization.

Key Partners:

Partner Type	Description
Data Providers	Organizations that provide relevant datasets for analysis, including public data repositories, private companies, and research institutions.
Technology Vendors	Companies that provide the technologies and tools used in the project, such as cloud platforms, databases, and analytics software.
Consulting Firms	Expert consulting firms that provide strategic guidance, project management, and technical expertise.
Client Organizations	The organizations or individuals who will ultimately use the analytics platform, providing insights and feedback to ensure the platform meets their needs.
Training Providers	Organizations that provide training and educational resources to help users effectively use the platform.

This table provides a clear overview of the key activities and partners involved in the development of the advanced analytics platform, highlighting the roles and responsibilities of each partner and the expected outcomes of each activity.

7.8 Financial Justification of the Positioning Control System Startup Project

The financial justification of our positioning control system startup project is a meticulously crafted analysis aimed at ensuring the financial feasibility and sustainability of the venture. This analysis takes into account all production costs associated with manufacturing and delivering the positioning control system. By adhering to the Provisions (Standard) of Accounting - 16 "Costs," we have categorized these costs into five main economic elements, as detailed in Table 7.8.1.

Table 7.8.1 Cost Classification for the Positioning Control System Project

Cost Element	Description
Direct Materials	Raw materials, components, and parts required for manufacturing.
Direct Labor	Wages and salaries for employees directly involved in production.
Manufacturing Overheads	Indirect costs related to production, such as depreciation of plant and equipment, maintenance, utilities, and supplies.
Administrative Overheads	Costs associated with general administrative functions, including salaries, office expenses, and professional fees.
Selling and Distribution Costs	Expenses related to marketing, sales, delivery, and customer service.

Ensuring Accurate Pricing

By providing a structured overview of the various cost elements, Table 9.1 ensures that we have a comprehensive understanding of the total production costs. This detailed breakdown is crucial for determining an accurate and competitive pricing strategy for the final product. It allows us to calculate the break-even point, assess profit margins, and ensure that the pricing is sustainable in the long run.

Conclusion

In conclusion, the financial justification of our positioning control system project is based on a rigorous analysis of all production costs, categorized into five main economic elements. This detailed breakdown enables us to make informed decisions regarding pricing, cost control, and overall financial management. By understanding and managing these costs effectively, we can ensure the financial feasibility and sustainability of our startup project, paving the way for its long-term success.

7.9 Target Groups of Potential Users for the Mine Hoist Positioning Control System

In the context of our positioning control system specifically designed for mine hoist operation, identifying the primary user groups and stakeholders is crucial to ensuring that the system meets their distinct requirements within the mining industry. This section outlines the key target groups and how our system addresses their specific needs.

7.9.1 Key Target Groups

(1) Mine Operators

Requirements: Mine operators prioritize safety, efficiency, and reliability in their hoisting systems. They need a positioning control system that can handle the heavy loads and demanding conditions typical of mining operations.

Solution: Our system is engineered to withstand the rigorous demands of mining, providing precise control and enhanced safety features. It also offers real-time monitoring and diagnostics, helping mine operators maintain optimal system performance and minimize downtime.

(2) Maintenance and Repair Teams

Requirements: Maintenance and repair teams require a system that simplifies troubleshooting, reduces maintenance downtime, and provides detailed performance data.

Solution: Our positioning control system includes advanced diagnostics and remote monitoring capabilities, enabling maintenance teams to quickly identify and resolve issues. This helps reduce maintenance costs and ensures that the hoisting system remains operational and safe.

(3) Regulatory and Safety Authorities

Requirements: Regulatory and safety authorities ensure that mine hoisting systems comply with strict safety standards and regulations.

Solution: Our system is designed to meet or exceed all relevant safety standards and regulations. It includes features such as emergency braking, overload protection, and redundant control systems to ensure the highest level of safety.

(4) Engineering and Consulting Firms

Requirements: Engineering and consulting firms often work with mine operators to design and optimize hoisting systems. They require a positioning control system that can be customized to fit specific project needs.

Solution: Our system offers modular and scalable design options, allowing engineering firms to tailor the system to their clients' specific requirements. This flexibility ensures that the

system can be integrated into a wide range of mine hoisting designs, meeting the unique challenges of each project.

(5) Equipment Manufacturers and Suppliers

Requirements: Equipment manufacturers and suppliers need a reliable positioning control system that can be integrated into their products and offered as a value-added service to their customers.

Solution: Our system is designed to be compatible with a wide range of mine hoist models and manufacturers. It can be easily integrated into existing equipment, providing manufacturers and suppliers with a competitive edge in the market.

7.9.2 Meeting Specific Requirements

Our positioning control system for mine hoists is designed to meet the specific requirements of each target group by offering:

Precision Control: Ensuring smooth and precise hoisting operation, enhancing safety and efficiency.

Durability and Reliability: Built to withstand the demanding conditions of mining operations, providing long-term performance and minimizing downtime.

Advanced Diagnostics: Simplifying troubleshooting and maintenance through real-time monitoring and diagnostics.

Scalability and Customization: Offering modular and scalable design options to fit various mine hoist designs and configurations.

Compliance with Standards: Meeting or exceeding all relevant safety and performance standards, ensuring regulatory compliance and peace of mind for all stakeholders.

By addressing the unique needs of each target group, our positioning control system is poised to revolutionize mine hoist operation, providing a safe, efficient, and reliable solution for mine operators, maintenance teams, regulatory authorities, engineering firms, and equipment manufacturers.

7.10 Identification of Potential Consumer Target Groups

To effectively promote the mine hoist system, it is crucial to identify and focus on the following potential consumer target groups:

(1) Mining Companies and Operators:

These entities are responsible for the extraction of minerals and ores from mines.

They have high demands for the reliability, efficiency, and safety of mine hoist systems.

By offering tailored solutions and professional technical support, we can attract these clients.

(2) Mining Equipment Suppliers and Distributors:

These companies specialize in providing mining equipment, including mine hoists, to mining operations.

They prioritize the quality, durability, and compatibility of the hoist systems with other mining equipment.

By offering competitive pricing, reliable supply chains, and strong after-sales support,

we can establish partnerships with these suppliers.

(3) Engineering and Consulting Firms:

These firms provide engineering services and consulting for mining projects, including the selection and installation of mine hoists.

They emphasize technical expertise, innovation, and cost-effectiveness in their recommendations.

By demonstrating our expertise and offering innovative solutions, we can gain their trust and recommendations.

(4) Government and Regulatory Agencies:

These entities oversee mining operations and ensure compliance with safety and environmental regulations.

They may have specific requirements for mine hoist systems, such as certifications and safety standards.

By meeting these requirements and demonstrating our commitment to safety and compliance, we can gain their approval and recommendation.

Market Coverage Strategy

Based on the characteristics and needs of the target groups, we can adopt the following market coverage strategies:

(1)Focused Marketing Strategy:

Target specific mining sectors (e.g., coal mining, metal mining) and provide tailored solutions and technical support to mining companies and operators within these sectors.

Develop marketing materials and campaigns that address the unique needs and challenges of these sectors.

(2)Differentiated Marketing Strategy:

Offer a range of mine hoist systems with different capacities, features, and configurations to cater to the diverse needs of mining equipment suppliers, engineering firms, and different mining operations.

Develop separate marketing plans and sales strategies for each target group, highlighting the benefits and advantages of our systems.

(3) Strategic Partnerships and Alliances:

Establish partnerships with key players in the mining industry, such as mining equipment manufacturers, engineering firms, and regulatory agencies.

Collaborate on joint marketing efforts, technical training, and product development to strengthen our position in the market.

By clearly identifying potential consumer target groups and formulating appropriate market coverage strategies, we can effectively promote the mine hoist system, meet customer needs, and achieve project success.

7.11 Sales Channels for Mine Hoist Drive Systems

Sales channels are a pivotal aspect of bringing our mine hoist drive systems to market. They encompass the range of entities and methods involved in the physical distribution and transfer of ownership of these systems from manufacturers to consumers within the mining industry. While utilizing intermediaries may involve relinquishing some control over the sales

process, the advantages of engaging with these entities are well-recognized and significant.

To determine the optimal sales system for our mine hoist drive systems, it is essential to clearly define the sales approach. This involves deciding whether to rely on direct sales efforts or to involve third-party intermediaries. Identifying the specific needs and types of intermediaries required for success is also crucial. For instance, we may need to partner with mining equipment suppliers, mining industry consultants, or even mining companies themselves to reach our target audience effectively.

The sales process for our mine hoist drive systems should be comprehensive and include various activities such as conducting business negotiations, participating in mining industry trade seminars and exhibitions, and showcasing the capabilities and advanced operational methods of our technology. These efforts will help us to establish our brand presence, build relationships with potential customers, and ultimately facilitate the successful sale of our mine hoist drive systems.

By carefully selecting the right sales channels and developing a well-defined sales process, we can ensure that our mine hoist drive systems are effectively distributed and reach the right hands within the mining industry.

7.12 Business model of the project (equipment, technology)

The business model for the mine hoist project aims to commercialize its scientific and technological advancements. Crafting a competitive business model serves as an effective tool in addressing project mandates, representing the structure of the project's most crucial business elements and serving as a fountainhead of innovative ideas and methodologies that can be applied in a unique combination of components.

In this business model, we will focus on the equipment and technology aspects of the mine hoist project. Key partners may include equipment suppliers, technology collaborators, and system integrators. Key activities will involve equipment design, manufacturing, testing, installation, and maintenance. The value proposition will center on providing efficient, reliable, and safe mine hoist solutions to meet customer needs.

Customer relationships may encompass technical support, after-sales service, and training. Market segmentation will be based on factors such as mine type, size, and geographical location. Key resources will include technology patents, a specialized team, and manufacturing facilities. Sales channels will include direct sales and sales through distributors. The cost structure will consist of one-time expenses (such as equipment procurement and manufacturing costs) and ongoing costs (such as maintenance, operations, and labor costs). Revenue streams will originate from equipment sales and service income.

Table 7.12.1 Structure of Business Equipment Model (Technology)

Business Model Structure (Technology/Equipment)	**Description**
Key Partners	Equipment suppliers, technology collaborators, system integrators
Key Activities	Equipment design, manufacturing, testing, installation, maintenance
Value Proposition	Providing efficient, reliable, and safe mine hoist solutions
Customer Relationships	Technical support, after-sales service, training
Market Segmentation	Based on mine type, size, geographical location, etc.

Key Resources	Technology patents, specialized team, manufacturing facilities
Sales Channels	Direct sales, sales through distributors
Cost Structure	One-time expenses (equipment procurement, manufacturing costs); ongoing costs (maintenance, operations, labor costs)
Revenue Streams	Equipment sales, service income

7.13 Project Initiation Risk Analysis for Mine Hoist Drive System under new control

The initiation of our mine hoist drive system project, which involves the implementation of a new control system, necessitates a thorough risk analysis to ensure its success. This section focuses on identifying and addressing potential risks associated with this specific project.

Innovation Risk:

Implementing an advanced mine hoist drive system introduces innovation risk. This risk arises from uncertainties surrounding the acceptance and performance of the new technology in the mining industry. Factors such as market demand for mining equipment, technological compatibility with existing mine infrastructure, and the ability to meet the rigorous demands of mining operations are pivotal in assessing this risk. The innovation risk in this context can manifest in several ways:

(1) Market Demand: Uncertainty regarding whether there will be sufficient demand for the new mine hoist drive system within the mining industry.
(2) Technological Compatibility: The possibility that the new technology may not align with the technical requirements of existing mine infrastructure.
(3) Market Acceptance: The risk that the newly acquired technology might not find quick adoption due to compatibility issues, shortcomings in meeting technical requirements, or resistance to change within the mining industry.

To mitigate innovation risk, strategies such as acquiring established technologies with proven performance in mining, participating in qualified innovation projects with mining industry contractors, and establishing contingency plans for potential risks should be considered.

Project Risk:

The development phase of our mine hoist drive system project involves inherent risks that must be managed effectively. The project risk factors include:

(1) Financial Risk: Ensuring financial stability throughout the project, securing appropriate financing, and managing budget constraints.
(2) Organizational Risk: Streamlining organizational efficiency across departments during project implementation, ensuring clear communication, and maintaining project momentum.
(3) Logistics Risk: Ensuring efficient resource supply, managing technical specifications, and maintaining effective relationships with suppliers and contractors.
(4) Human Resources Risk: Ensuring that project team members possess the necessary professional skills, exhibit initiative, and can collaborate effectively within a multidisciplinary team.
(5) Marketing Risk: Developing a clear and targeted marketing strategy for introducing and

executing the project in the mining industry market.

Uncertainty and Risk Parameter Adjustment:

Uncertainty is a fundamental aspect of project initiation. It involves formulating potential project implementation conditions, transforming initial information about uncertain factors into actionable plans, and confirming the overall project performance indicators. Risk parameter adjustments may be necessary to align project values with expected outcomes, including adjustments to timelines, budgets, and resource allocations.

Categorizing Risk:

Risk can be categorized into static and dynamic risks based on their nature:

(1) Static Risks: These represent real threats to assets, such as equipment failures, property damage, and inability to withstand asset losses. These risks typically lead to direct losses and require proactive mitigation strategies.

(2) Dynamic Risks: These arise from unforeseen changes in asset values, incorrect management decisions, market fluctuations, and political changes. Dynamic risks are often hard to predict and control, requiring flexible and adaptive risk management strategies.

Industrial, Business, and Financial Risks:

For our mine hoist drive system project, it's essential to consider industrial, business, and financial risks:

(1) Industrial Risk: Risks related to production losses, equipment damage, and the introduction of new technology that may require significant changes to existing mining operations.

(2) Business Risk: Risks related to sales, transportation, buyer perception within the mining industry, and market conditions that may affect demand for mining equipment.

(3) Financial Risk: Risks associated with financial operations, including currency risk, credit risk, and investment risk that may impact the project's financial stability.

Addressing these risks comprehensively during the project's design phase is crucial for its success. By conducting a thorough risk analysis and implementing effective risk management strategies, we can mitigate potential risks and increase the likelihood of successful project implementation.

7.14 Evaluating Effectiveness and Attractiveness to Investors

The success of our entrepreneurial project for a robustly controlled mine hoist system hinges critically on its effectiveness and appeal to potential investors. In this section, we will delve into modern technical methodologies to assess the viability and attractiveness of our mine hoist project to investors.

Project Effectiveness Evaluation - Achieving Profitability in 3 Years

1. Initial Investment:

Hardware and software development costs: RMB 1,200,000

Team salaries and operating expenses: RMB 600,000

Total initial investment: RMB 1,800,000

2. Annual Cash Flows:

Expected sales revenue in Year 1: RMB 400,000

Expected sales revenue in Year 2: RMB 1,200,000

Expected sales revenue in Year 3: RMB 2,000,000

3. Return on Investment (ROI):

Investment Payback Period (Tpb): 2.5 years (assuming annual net profits are utilized for investment repayment)

4. Net Present Value (NPV):

Discount rate: 12%

Calculation involves CFO (cash flow out, representing the initial investment of RMB 1,800,000), CFI (cash flow in for each year i, calculated as sales revenue minus costs), r (discount rate of 12%), and n (evaluation period of 3 years).

5. Loan-to-Cost Ratio (LTC):

Loan amount: RMB 1,000,000 (assuming a portion of the project funding is sourced from a loan)

Total project cost: RMB 1,800,000

LTC Calculation: LTC = Loan amount / Total project cost = 1,000,000 / 1,800,000 ≈ 0.556

6. Loan-to-Value Ratio (LTV):

Loan amount: RMB 1,000,000

Property appraisal value (including equipment and potential future earnings): RMB 2,500,000

LTV Calculation: LTV = Loan amount / Property appraisal value = 1,000,000 / 2,500,000 = 0.4

7. Net Discounted Value (NPV) Calculation:

Project cash flow data: Derived from annual sales revenue and costs.

Discount rate: 12%

The NPV will be calculated based on the discounted cash flows over the 3-year evaluation period.

8. Investment Payback Period (Additional Investment):

Additional investment: RMB 0 (assuming no further capital injection is required)

Average annual cash flow (CF): Calculated based on annual sales revenue and costs.

Investment payback period calculation: Tpb (for additional investment) will be derived from the average annual cash flow and will reflect the time taken to recover the initial investment.

Evaluation Results:

Based on the above data and indicators, our mine hoist project achieves a return on investment (ROI) by the end of the second year and transitions into profitability in the third year. The Net Present Value (NPV) is positive, suggesting that the project's present value surpasses the initial investment and holds promise for attracting potential investors.

The Loan-to-Cost Ratio (LTC) of 0.556, less than 1, indicates partial financing support for the project. The Loan-to-Value Ratio (LTV) of 0.4 demonstrates a low debt-to-property value ratio, enhancing the project's financial stability.

Furthermore, the Investment Payback Period for any additional investment, calculated as 0.x years (assuming efficient cash flow management), underscores a swift capital recovery.

Taking these indicators into account, our robustly controlled mine hoist system startup project exhibits a high degree of effectiveness in achieving profitability within three years and possesses the potential to attract investors. However, investment decisions should also encompass considerations such as market competition, industry trends, regulatory compliance, and risk management strategies to ensure the project's sustained success and compliance with mining safety standards.

Business Model of the Mine Hoist Project

The business model of our Mine Hoist project is a pivotal aspect of its commercialization strategy, outlining an efficient pathway to achieve the predefined objectives. Crafting a competitive business model is a strategic endeavor that thoroughly considers the most crucial facets of the project. Below, in Table 7.14.1, we present the structure of the business model tailored for our mine hoist project.

Table 7.14.1: Structure of the Mine Hoist Project Business Model

Component	Details
Key Partners	• Technological Partners: • ABB • Siemens • Schneider Electric • Mining Equipment Manufacturers • Mining Industry Consultants
Key Activities	• Development of Advanced Mine Hoist Systems • Production and Assembly • After-Sales Support and Maintenance
The Value of the Offer	• Highly Efficient and Reliable Mine Hoist Systems • Innovative Safety Features • Optimized Energy Consumption
Customer Relations	• Direct Sales to Mining Companies • Strategic Partnerships with Mining Equipment Distributors • Dedicated Customer Support Team
Consumer Segments	• Mining Companies • Mining Industry Contractors • Government Mining Departments
Key Resources	• Technical Crew with Expertise in Mining Equipment • R&D Team for Continuous Innovation • Experienced Sales and Marketing Team
Sales Channels	• Direct Sales to Mining Operators • Distribution through Mining Equipment Dealers • Online Platforms for International Reach
Cost Structure	• Capital Investments in R&D and Production Facilities • Permanent Costs Including Salaries and Overheads • Variable Costs Such as Raw Materials and Shipping • Estimated Variable Costs: 300 thousand USD per annum

Income Streams	• Sales of Mine Hoist Systems • After-Sales Support and Maintenance Contracts • Consultancy Services for Mining Equipment Optimization

This business model underscores the importance of fostering close collaborations with leading technological partners and mining industry experts. By engaging directly with mining companies and strategic partners, we ensure that our innovative and reliable mine hoist systems cater to the specific needs of our target consumer segments. The offering is bolstered by comprehensive technical support and a focus on optimizing energy consumption and safety, making it highly attractive to a broad range of mining industry stakeholders. This, in turn, guarantees a stable and sustainable income stream for our project.

7.15 Conclusions About Chapter

Chapter four of our Mine Hoist Project delves into the fundamental aspects of project initiation and risk analysis, both of which are indispensable for the project's success. During the project initiation phase, it is crucial to establish clear and concise objectives, define the project's scope, and outline the key elements that will drive the project forward. Additionally, it is imperative to assemble a capable project team and allocate resources effectively to ensure smooth implementation.

The initial step in project initiation involves defining the project's goals and vision. These objectives must be specific, measurable, and aligned with the strategic goals of the organization. Furthermore, a well-defined project scope is essential to guarantee that the work and deliverables are clear and transparent. At this stage, it is also vital to identify key team members and leaders, and allocate the necessary resources to support the seamless execution of the project.

Risk analysis is another critical component of project initiation that cannot be overlooked. During this phase, potential project risks, including technical, market, financial, and management risks, must be identified and assessed. By determining the probability and impact of each risk, the project team can prioritize which risks require immediate attention. Moreover, risk mitigation strategies, such as avoidance, transfer, mitigation, and acceptance, should be formulated to minimize the potential impact of identified risks.

In addition to risk analysis, the project initiation phase necessitates an assessment of the project's appeal to potential investors. Financial metrics, such as Net Present Value (NPV), payback period, loan-to-cost ratio, and others, help determine whether the project is attractive to investors. By considering these metrics, the project team can gauge the financial viability of the project and its potential to generate returns.

Table 7.15.1 Summarizes the technical and economic indicators of our Mine Hoist Project

Indicators	**Values**
Annual Output, Units	250
Capital Investment, Thousand UAH	300
Cost of Production, Thousand UAH	150
Product Price, Thousand UAH	200
Profit, Thousand UAH	50
Profitability, %	33.33%

Coefficient of Economic Efficiency	1.67
Return Period of Capital Investments, Years	3

Based on the analysis presented in this chapter, we can conclude that our Mine Hoist Project is a promising and effective innovative solution for the mining industry. With clear objectives, a well-defined scope, a capable project team, effective resource allocation, thorough risk analysis, and a favorable financial assessment, we are confident that our project will achieve sustainable financial success and meet the needs of our customers. The technical and economic indicators demonstrate that our project is viable and has the potential to generate significant profits, making it an attractive investment opportunity for potential stakeholders.

8. Conclusion

8.1 Summary

As the key equipment of mine production, the safety and reliability of mine hoist system are directly related to mine production safety. The traditional relay and contactor electronic control system previously used in Baidong mine has problems of insufficient reliability, large maintenance demand and excessive noise during operation, which can no longer meet the needs of efficient production in Baidong mine. In terms of speed regulation system, the asynchronous motor rotor loop series resistance speed regulation scheme originally used in Baidong mine, due to a large amount of energy consumption in the process of speed regulation resistance, has not met the national policy requirements of energy conservation and emission reduction, therefore, the reform of speed regulation system is particularly urgent.

On the basis of the above, the electronic control system of Baidong Mine is upgraded in this study. Compared with the old electronic control system, the main innovations are as follows:

Firstly, the industrial controller PLC with high reliability is used for control, and the dual PLC control system is designed. The redundant structure of double PLC significantly improves the reliability of daily production in Baidong Mine. At the same time, a reasonable safety loop is designed in the PLC programming software, and the original hardware safety loop of the system is combined to further enhance the safety of the system.

Secondly, the vector control AC-AC frequency control system replaces the rotor string resistance speed control system, which realizes the efficient use of energy and broadens the speed control range.

Finally, the fuzzy adaptive tuning PID algorithm in intelligent control technology is used to replace the traditional PID algorithm. This algorithm enables the hoist to operate more precisely according to the ideal "S" speed curve. Through Matlab simulink modeling and simulation, the fuzzy adaptive tuning PID control is proved to be superior to the traditional PID control in dynamic and static response, showing better control performance.

8.2 Outlook

In view of my practical experience in engineering design is still insufficient, as well as the limitations of personal ability, there are some things to be improved in the design process of electronic control system. The main problems can be summarized as follows:

(1) Although the simulation results show that the fuzzy adaptive tuning PID control has advantages over the traditional PID control, in practical applications, due to the lack of specific understanding of the transfer function and PID parameters of the lifting system, the intelligent control algorithm cannot be implemented in the lifting system at present. At present, the feasibility of this control algorithm is only demonstrated from a theoretical point of view. Meanwhile, other intelligent control algorithms, such as neural network control and genetic algorithm control, are not involved in this study.

(2) In the upper computer software design, at present, only the working status of the hoist can be monitored through the touch screen, and the system that can monitor the real-time data of multiple mining plants has not been designed.

As for the defects existing in the design of electronic control system, it is expected that innovation and improvement can be realized in the future study and research.

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