Design of Frequency Conversion and Soft Start Cooperative Control System for Mine Fan

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Abstract. In order to improve the safety and reliability of mine fan control system and realize remote control in dual operation modes, a cooperative control system of frequency conversion and soft start of mine fan was developed based on PLC. On the basis of analyzing the position of coal mine in China's economic development and the role of coal mine ventilation system, this paper expounds the working principles of mine soft starter and mine frequency converter, and designs a cooperative control system of mine fan frequency conversion and soft start based on PLC, which realizes remote control of mine fan starting, running and stopping, and has the functions of voltage, current, wind speed and air volume parameter monitoring and fault protection.

Keywords: Mining fan, cooperative control, frequency conversion, software program.

1. Introduction
In recent years, China's economy has entered a new period of high-quality development. As the main body of energy structure, coal's position in the national economic development and national energy security has been continuously improved. For a long time, coal has been the main body of China's energy structure. Although the new energy industry has developed rapidly in recent years, it is restricted by the characteristics of China's energy structure of rich coal, poor oil and less steam, the high degree of dependence on new energy environment and the bottleneck of energy storage technology development. In the future, the dominant position of coal will not change. In the process of coal mining, safety is the first consideration. Although in recent years, the total number of coal mine safety production accidents and million ton mortality continue to decline, but the hidden dangers of coal mine safety production accidents have not been completely eliminated, coal mine safety production is still the focus of work in the future.

There is a large amount of gas in coal and rock. In the process of coal mine safety production, the coal and rock will be destroyed by external forces, which will lead to the rapid emission of gas. If the gas can not be eliminated in time, there will be gas explosion, staff hypoxia and other safety production accidents. It refers to the use of fresh air and dust in the mine ventilation system to increase the concentration of toxic gases and exhaust harmful gases. The basic tasks of mine ventilation system...
are: supply enough fresh air underground to meet the needs of underground workers for oxygen; Reduce the content of gas, carbon monoxide and dust in coal mines to ensure the safety of underground production and the safety of workers; Adjust the underground climate and create a good working environment. Fan is the main equipment of ventilation system in coal mine, and its safety is directly related to the smooth development of safety production in coal mine. Most of the existing underground fans are directly controlled by mine flameproof electromagnetic starter, which has the defects of large starting current, low reliability and high failure rate. Therefore, it is of great theoretical and practical significance to carry out the research on the cooperative control of frequency conversion and soft start of mine fan and realize the dual-mode operation of fan and frequency conversion.

2. Mine fan system
Mine fan system is responsible for transporting fresh air in coal mines, removing harmful gases such as gas and dust, and ensuring the safety of production in coal mines and the safety of life and property of underground miners. According to the requirements of pressure, air volume, wind speed and temperature in coal mine safety production, the mine fan system is reasonably controlled and adjusted. At present, the most commonly used method for controlling and regulating speed of mine ventilation system is to adjust the opening of air door and baffle. This method requires the fan to run at full speed regardless of the wind speed requirement, which causes energy waste and equipment loss in the actual operation process, thus increasing the cost of coal mine safety production and equipment maintenance workload, shortening the service life of fan system, and bringing potential accidents for coal mine safety production. Most of the existing fans are asynchronous motors, which are directly driven by mine flameproof low-voltage electromagnetic starters. There are some shortcomings, such as large starting current, large mechanical impact and poor safety protection characteristics, which not only affect the service life of equipment, but also affect the safety of underground power grid in coal mines, and easily lead to fan system damage and motor burning.

The soft starter of mine fan uses three-phase parallel thyristors such as three-phase full-control bridge rectifier circuit as voltage regulator, which is connected between power supply and motor stator. When the soft starter of mine fan starts the fan machine, the output voltage of thyristor gradually increases, and the motor gradually accelerates until the thyristor is fully turned on, and the fan works on the mechanical characteristics of rated voltage, thus realizing smooth start, reducing starting current and avoiding starting overcurrent trip. When the fan reaches the rated speed and the starting process is over, the soft starter of mine fan automatically replaces the thyristor with the bypass contactor to provide the rated voltage for the normal operation of the fan, so as to reduce the heat loss of the thyristor, prolong the service life of the soft starter, improve its working efficiency, and avoid the harmonic pollution of the power grid. The soft starter of mine fan also provides the function of soft stop. The process of soft stop is opposite to that of soft start. The voltage gradually decreases and the speed gradually drops to zero to avoid the torque impact caused by free stop.

The main circuit of mine fan frequency converter is the power conversion part that provides voltage regulation and frequency modulation power supply to the fan. The main circuit of mine fan frequency converter can be divided into two categories: voltage type is a frequency converter that converts DC of voltage source into AC, and the filtering of DC circuit is capacitor. The current mode is a frequency converter that converts the DC of current source into AC, and its DC loop filter is inductance. The frequency converter of mine fan is composed of rectifier unit, filter unit and inverter unit. The rectifier unit transforms the power frequency power supply into DC power supply, the inverter unit transforms the DC power supply into AC power supply, and the filter unit absorbs the voltage pulsation generated by the rectifier unit and inverter unit. The frequency converter of mine fan is suitable for the dangerous environment with coal dust, gas and other explosive gases in the coal mine. It can automatically control the local fan in the coal mine, and automatically adjust the speed of the wind speed according to the gas concentration of the working face, so as to realize the normal ventilation and emission of the fan in the coal mine. Under the mode of automatic frequency setting, the frequency converter of mine fan controls the automatic speed regulation operation of the fan.
according to the gas concentration signal to make the local fan work in the state of automatic ventilation, automatic gas drainage or shutdown, so as to realize the safe operation of the local fan. The frequency converter of mine fan is shown in Figure 1.

![Figure 1](image.png)

**Figure 1** The physical object of the mine fan inverter

### 3. Control system design

The cooperative control system of frequency conversion and soft starter of mine fan adopts PLC as the core device, mainly including PLC, touch screen, transformer, power distribution device, switching device, frequency converter, soft starter, mine fan, wind speed sensor, air volume sensor, data processing unit, control unit, communication module, etc. The transformer, power distribution device, switching device, frequency converter and soft starter are the main control circuit of mine fan, and the transformer converts the grid voltage into the power supply voltage of the fan; the power distribution device is composed of low-voltage circuit breaker and protector, which is used to realize the power control of the whole power supply system and has the protection functions of over-current, overload short circuit and leakage; the switching device is composed of double circuit switch, which is used to realize the power supply control of the whole power supply system To realize the free switching between the frequency converter and the soft starter; the frequency converter and the soft starter are used to control the start and stop of the mine fan; the wind speed sensor and the air volume sensor are used to collect the operation parameters of the mine fan; the data processing unit is used to convert the analog signal output by the wind speed sensor and the air volume sensor into the digital signal that can be recognized by PLC; the control unit is used to send the start and stop signals of the mine fan Stop and stop signals. The structure of mine fan frequency conversion and soft start collaborative control system is shown in Figure 2.
Figure 2 The frequency conversion and soft start cooperative control system of mine fan

The touch screen in the cooperative control system of frequency conversion and soft start of mine fan is configured by McgsPro configuration software, which is used to display the information such as the setting of mine fan operation parameters, soft start operation indication, inverter operation indication, inverter operation current, three-phase voltage value, three-phase current value, system fault display, inverter operation frequency, soft start operation current, wind speed and air volume of mine fan. The touch screen configuration screen consists of main screen, status monitoring, instrument display, parameter setting, real-time curve, history curve, XY curve, alarm browsing, save browsing, after-sales service, etc. The parameter setting interface of mine fan frequency conversion and soft start collaborative control system is shown in Figure 3. The instrument display of mine fan frequency conversion and soft start collaborative control system is shown in Figure 4. The real-time curve of mine fan frequency conversion and soft start collaborative control system is shown in Figure 5.
Figure 4 The instrument display of the frequency conversion and soft start cooperative control system of the mine fan

Figure 5 Real-time curve display of the frequency conversion and soft start cooperative control system of mine fan

The software of mine fan frequency conversion and soft start collaborative control system is used to realize the functions of system parameter setting, mine fan start, operation parameter collection, fault judgment, mine fan protection, mine fan stop and so on. The system software is developed by the special programming environment of PLC, STEP 7-MicroWIN SMART. The interface of STEP 7-MicroWIN SMART has project tree, menu bar, instruction area, programming area, etc. Select PLC option in the menu and set the connection parameters accordingly. Set the network card used by our computer in the communication setting interface, and confirm the name of the network card used by us.
After the setting is completed, the "flashing indicator light" button on the right side of the motor panel indicates that the setting is successful if the red and yellow LED lights flash. The software flow of mine fan frequency conversion and soft start collaborative control system is shown in Figure 6.

**Figure 6** The software flow of the frequency conversion and soft start collaborative control system of mine fans

4. Conclusions

In view of the disadvantages of high starting current and large energy consumption in coal mine ventilation system, the hardware circuit and software program of mine fan frequency conversion and soft start cooperative control system are developed based on PLC, and the dual-mode starting and stopping of mine fan is realized. At the same time, it has the functions of parameter monitoring and fault diagnosis, which provides reference for the design of intelligent ventilation system in coal mines and the construction of intelligent mines.

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