Development of monitoring and control system for a mine main fan based on frequency converter

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Abstract: In the process of mine exploitation, the requirement of air flow rate often changes. The procedure of traditional control mode of the fan is complex and it is hard to meet the worksite requirement for air. This system is based on Principal Computer (PC) monitoring system and high performance PLC control system. In this system, the frequency converter is adapted to adjust the fan speed and the air of worksite can be regulated steplessly. The function of the monitoring and control system contains on-line monitoring and centralized control. The system can monitor the parameters of fan in real-time, control the operation of frequency converter, as well as, control the fan and its accessory equipments. At the same time, the automation level of the system is highly, the field equipments can be monitored and controlled automatically. So, the system is an important safeguard for mine production.

1. Introduction
In the process of mine exploiting, the main fan supplies enough fresh air to the staff underground, dilutes harmful gas and dust to create good working environment. It is an important way to guarantee mine safety production by equipping a set of perfect monitoring and control system for the fan. At the initial stage of mine constructing and exploiting, the requirement of air is little and often changes. The procedure of traditional control mode is complex and it can’t adjust the air steplessly. The main mine fan monitoring system designed in this paper bases on frequency converter system, the hot redundancy PLC and configuration software. This system has been used in a certain mine main fan system. This system can monitor the main fan running parameters, diagnose the equipment fault and measure its performance parameters. Also, the system can regulate the fan speed steplessly. This adjusting way has significant energy-saving effect in the mine construction stage particularly.

2. Hardware design of the system
Hardware is equipped to improve the reliability of the system, for example, the Schneider Quantum series 67160 PLC is adapted to be the main control unit of this system and the ADVANTECH 610H industrial control computer is used to be the Human-Computer Interaction (HMI) unit. Also, the hardware of the system includes functional modules and sensors, such as PLC control modules, field sensors, execution units, and so on. The hardware constitution of this system is complex, the structure of the constitution is shown in figure 1.
The system can monitor the performance of fan equipment, the parameters of running converter, the state of switch cabinet, the position of fan gate, etc. It is realized by collecting signals of all kinds of sensors. The signals needed to be gathered are much more in this system, they are shown in figure 1. Field signals are produced by all kinds of intelligent sensors and transducers, the models of sensors are confirmed according to the scene of the environment and characteristic of signal. In this system, the PT100 temperature sensor is used to measure the temperature of fan bearing and motor bearing; the YD-188GF explosion-proof vibration sensor is used to measure the vertical and horizontal vibration of fan and motor bearing; the JYB-KO negative pressure sensor is used to measure the negative pressure of intake roadway and fan inlet; the position of fan air door is confirmed by the feedback signal produced by executive motor. The outputs of these sensors are standard 4-20 mA current signals, these signals are collected by the PLC system directly. In addition, the motor electric parameters and the frequency converter parameters are collected by the way of RS485 communication.

The output signals of sensors are easily to be interfered by external environment, because they are all small weak current signals. It is needed to take necessary anti-jamming and isolation measures to eliminate the external interference when hardware system is designed. So shielded cables are adapted to be signal cable and the shield is grounded. The anti-jamming industrial control computer is used as HMI system, and UPS is adapted to be the power source of the HMI system to prevent the power interference. The output signal of sensor is anti-interference DC signal to eliminate the attenuation of signal transmission effectively. As well as, the power cable and the control cable should be arranged separately.

The safety operation of the system is determined by the operational status of the PLC, because the data acquisition and intelligent control of the whole system are undertaken by PLC. Accordingly, Schneider Quantum series 67160 PLC, in this system, is used to construct the redundancy control system. This system has dual control core and they can switch automatically, which enhances the reliability of the fan operation.

The HMI system provides a good interactive platform; it provides a way for staff dialoguing with the controlled equipment. It can display the performance parameters of the equipments, record and print history data. Also, the system has the function of remote operation and network communication, etc.

Figure 1. Composition diagram of monitoring and control system
3. The software design of the monitoring and control system
Software system is the protection to achieve the main function of the monitoring and control system. In this system, software system constituted with two main components: PLC control unit software and HMI system software.

3.1. PLC software system
PLC system is not only the acquisition unit of the fan monitoring and control system but also the control core of the entire system, the reliability of the system is influenced by the design of PLC software directly. According to the functions of the system, the PLC program is modular, and every module is designed separately. The advantages of adapting modular design are that the program structure is clearly, the function is easy to be extended and modified conveniently. The main functions of the PLC system are more, such as acquire data, control converter, experiment, operate locally, operate automatically, switch in fault and diagnose automatically. In the process of software design, the above-mentioned functions are implemented by the corresponding functional modules, the whole PLC software is composed by them organically according to the requirements of the monitoring system.

3.2. The software design of HMI system
A good monitoring platform is provided by HMI system for field staff, it must meet the field requests, such as friendly interface, convenience operation and perfect assistance functions, etc. The ForceControl configuration software is used to design and develop the HMI system in this monitoring and control system.

Real-time data can be acquired reliably by the developed HMI software system from the PLC system, and these data will be displayed on the screen after processed by the HMI system. The running status of fan equipment is simulated in graphical form by the HMI system, and the status is displayed on the computer screen intuitively. On the other hand, field staff can operate and control fan equipment on the human-machine interface, such as start-stop of hydraulic station, opening of fan air door, on-off of frequency converter, switch of fan, and so on. In addition, the performance parameters of fan equipment can be measured by making use of this system, so that performance state of fan can be grasped. At the same time, the HMI system has remote communication function, so, the processed data can be sent to the control center through the Ethernet.

4. Functions and features of monitoring and control system

4.1. Functions of the system
Main function of fan monitoring system is to monitor the parameters of fan accurately, control and diagnose the equipment according to the running state, protect the operation safety of fan equipment. The main running interface of the system is shown in figure 2. It shows the main functions of the system, and the functions are:

- Monitors the parameters of fan, such as negative pressure, surge, flow, bearing temperature, vibration, process energy consumption, etc.
- Monitors the parameters of motor, for example, voltage, current, frequency, power, bearing temperature, speed, etc.
- Inquire and print the real-time & historical parameters, such as temperature, vibration, power, flow, etc.
- Record the operation performed by field operator.
- Generate characteristic curve of fan dynamically and measure the performance of fan regularly.
- Transmit data remotely.
4.2. Features of the system
The frequency converter and the intelligent control unit of fan gate are adapted in the monitoring and control system. The characteristics of the system are followed.

4.2.1. Control the fan flow accurately. The fan flow is jointly controlled by frequency converter and feedback signal of negative pressure in this system. The frequency can be adjusted by PLC control program. It is known from the motor speed formula that the motor speed can be adjusted by frequency. According to the proportionality law \[3, 4\], the relationships between \(n\) (rotational speed) and \(Q\) (flow rate), \(H\) (pressure), \(N\) (shaft power) are, respectively, expressed as

\[
\frac{Q}{Q'} = \frac{n}{n'}, \quad \frac{H}{H'} = \left(\frac{n}{n'}\right)^2, \quad \frac{N}{N'} = \left(\frac{n}{n'}\right)^3
\]

It is known from the above equations that the characteristic parameters of fan can be adjusted by regulating the given frequency of converter. Compared with traditional adjustment model, it is simple to adjust and easy to operate, in addition, the air flow can be regulated steplessly and accurately.

4.2.2. Switch automatically in fault condition. In the process of production, the downtime of main fan can not be more than ten minutes according to the rule of “Safety Regulations in Coal Mine”. Therefore, the function of switching automatically in fault condition is set up in this system. The system will check out the standby fan when the running fan equipment stops due to fault, the standby fan will be started in two minutes when it is ready to start. At the same time, the system alarms with sound and light, reminds the field staff to repair the fault fan. When switch the fan normally, this monitoring system can keep wind to switch the fan.

5. Conclusions
The control core of this system is redundancy PLC, and the HMI development platform is ForceControl configuration software. This system is developed based on frequency converter. The performance parameters and status of fan can be monitored and controlled in real-time, and the
performance of fan will be measured regularly. In this system, many aspects are researched thoroughly, such as flow regulation, condition monitoring and diagnostics, integrated monitoring and control, etc. This system has been applied to a main fan of Hongyi Mine of Aluminum CPIC Ningxia, Yinchuan, it shows that the reliability of the main fan equipment is improved by using the system, and the safety production is also guaranteed.

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