Research of vibration controlling based on programmable logic controller for electrostatic precipitator

Zisheng Zhang*, Yanhu Li, Jiaojiao Li, Zhiqiang Liu, Qing Li
Electrostatic Research Institute, Hebei University, No.180 Wusidong Road, Baoding, China
E-mail: zhangzisheng@hbu.edu.cn

Abstract. In order to improve the reliability, stability and automation of electrostatic precipitator, circuits of vibration motor for ESP and vibration control ladder diagram program are investigated using Schneider PLC with high performance and programming software of Twidosoft. Operational results show that after adopting PLC, vibration motor can run automatically; compared with traditional control system of vibration based on single-chip microcomputer, it has higher reliability, better stability and higher dust removal rate, when dust emission concentrations \( \leq 50 \) mg m\(^{-3}\), providing a new method for vibration controlling of ESP.

1. Introduction
At present, the dust pollution in China is mainly produced from cement, coal-fired power and metallurgy, and the emission of coal-fired power plant is increasing day after day. The process of coal-fired power will produce a large number of coal-dust. What’s more, the coal-dust is harmful to health of human [1]. Every year, coal-dust not only causes air pollution, but also leads to huge waste of resources. Therefore, we must take control of coal-dust pollution.

Electrostatic precipitator (ESP) is a kind of popular device which can capture particles; which has obvious advantage [2]. The motor’s vibration control system is directly related to efficiency of ESP. The traditional vibration is based on single-chip microcomputer, but it has some disadvantages. For example, its circuit is complex, consumption of power is high, and program of single-chip microcomputer is easy to break down when electromagnetic interference (EMI) occur. The reliability and stability of traditional vibration control system is lower, and the result is to reduce efficiency of removing dust. In recent year, programmable logic controller (PLC) is widely used in industrial environment; PLC is substituting for single-chip microcomputer as control core of ESP, which can improve the efficiency of removing dust, and is a kind of ideal design scheme.

2. Improved plan of vibration control
Schneider PLC has powerful functions, which adopts I/ O photoelectric isolation and filter on the hardware; and adopts fault detection and alarm to insure reliability and stability on the software. Besides, it has many communication modules, just like RS232/485. Therefore, we choose Schneider PLC as cybernetics core [3].

Diagram of vibration controlling is shown in figure 1 [4]. The main control process includes four parts: vibration of gravity separator chamber, vibration of the 1st, 2nd and 3rd electric field. PLC can

* To whom any correspondence should be addressed.
communicate with computer through RS485 port, and then sends the collecting data to the computer to monitor the site. Meanwhile, computer also appropriately modifies internal timer and counter of PLC, to make ESP work at the best state.

2.1. Experiment device

Figure 2 is the schematic diagram of vibration device. The ESP has the strict request for resistance of dust, the dust resistance is in the range of 105-1011 Ω·cm. In the case of the resistance of dust is above 1011 (high resistance type), the electric field will against electric corona, leading to reducing the efficiency of removing dust. The coal-dust belongs to the type of high resistance, and the temperature is about 350 °C. Before coal-dust goes into the draught fan, gas goes through the humidifying tower to reduce the resistance of dust first, and then passes through gravity separator chamber and three electric fields; finally, the gas is expelled by the flue.

2.1.1. Control Circuit

The equipment has a gravity separator room and 3 electric fields. The applied voltage is fixed at 75 kV. As shown in figure 2, M1, M3 and M5 are motors which are at the anode, while M2, M4 and M6 are motors which are at the cathode. M10 and M11 are motors which are on both sides of gravity separator chamber.
separator room. M7 and M8 are motors which control YM1 and YM2 that are electromagnetic valves [5]. Through motor’s forward and inversion, M7 and M8 enable YM1 and YM2 to be opened and closed.

In order to prevent dust flying again, both of two motors in the same electrical field and the adjacent motors located at the adjacent electric fields can not work at the same time.

The timing design of gravity separator chamber: When the signal of starting arrives, M10 works immediately. It works for 3 minutes, and stops for 7 minutes; next, M11 stops for 7 minutes, and then works for 3 minutes. The first cycle is over. The after cycle is triggered by timer [6].

The timing design of the 1st electric field: When the signal of starting arrives, M1 also works immediately. It works for 2 minutes, and then stops for 8 minutes. M2 vibros cathode, stops for 8 minutes, then works for 2 minutes. The first cycle is over. The after cycle is triggered by timer.

The timing design of the 2nd electric field: When the signal of timer triggers, the first vibration of M3 starts. It stops for 18 minutes, then works for 2 minutes. M4 vibros cathode, works for 2 minutes, and then stops for 18 minutes. The first cycle is over. The after cycle is triggered by timer.

The timing design of the 3rd electric field: When the signal of timer triggers, the first vibration of M5 starts. It works for 2 minutes, and then stops for 28 minutes. M6 vibros cathode, stops for 28 minutes, then works for 2 minutes. The first cycle is over. The after cycle is triggered by timer [7].

When M5 and M6 work, the dust may be taken away by the airflow. To get a better efficiency of dedusting, when M5 works, the valve of YM1 shuts off; YM1 opens after M5 stops for 2 minutes. In the case of M6 works, the valve of YM2 shuts off; then YM2 opens after M6 stops for 2 minutes.

2.1.2. The design of wiring
According to the control requirements, this system chooses TWDLCAE40DRF type of PLC. The wiring diagram is shown in figure 3.

![Figure 3. The wiring diagram of I/ O for PLC.](image)

2.2. The design of program
When the switch of system is turned to automatic switch (I17 is on), system will work according to the settled time. However, when the switch of system is turned to hand switch (I16 is on), the system is controlled by hand switch. At the same time, PLC don not work.

As shown in figure 4, if the button of start (I0) is on, M0 switches to open. System carries out 5 subroutines. They are L0, L1, L2, L3 and L4.
As shown in figure 5, the state of M0 switches to open when the start button is pressed. At the same time, Q0.6 is flicked to “on”, M10 starts the first vibration. The timer (TM0) starts to work for 2 minutes. When the time is up, Q0.6 is reset \[8\], and then M1 stops working. Meanwhile, Q0.7 switches to “on”, M11 starts to work, and the timer (TM1) works for 2 minutes; when the time is up, the timer (TM2) starts to work for 6 minutes, M1 works again. The first cycle is over. The programs of three electric fields are similar with the gravity separator chamber, so we do not repeat any more \[9\].

As shown in figure 6, when M5 works, M7 turns forward and YM1 is closed; after M5 works for 2 minutes and delay for 2 minutes, M7 starts to inverse, then open YM1 to discharge the gas; when M6 works, M8 turns forward and YM2 is closed. After M6 works for 2 minutes and delays for 2 minutes, M8 starts to inverse then open YM2 to discharge the gas \[10\].

3. Conclusion
The innovation point of the paper is substituting PLC for single-chip microcomputer control vibration of motor in the electric field of ESP, to improve stability and reliability. One the one hand, this design
optimizes original vibration control system of electrostatic precipitator (ESP), makes the gas go through the humidifying tower to reduce resistance, and then go into the ESP. On the other hand, adding vibration of gravity separator room to improve dust removal efficiency. The operation’s result shows that the design is reasonable and effective, has strong anti-interference and reliability. The design can meet the National effluent standard which is no more than 50 mg m$^{-3}$

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