

The Research of PLC and Touch Screen in the Erosion of Coating of Wind Turbine Blade

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Abstract: Inner Mongolia is located in the north of China, where the development of wind power industry is outstanding. Because of the surrounding environment's destruction by frequent sandstorm phenomena in recent years, wind fan blades are severely damaged. The purpose of this paper is to use PLC and touch screen to realize quantitative content of sediment erosion wear in accurate control. The whole test system with high precision and accurate control, has a practical value in the study of the fan blade abrasion.

Keywords: Control system, PLC, quantitative control, sediment concentration, touch screen.

1. INTRODUCTION

Inner Mongolia located in the north of China, has unique natural wind power resources; therefore the grid distribution is wide. But in recent years, frequent sandstorm phenomenon lead to a lot of heavy damage to fan blade coating [1]. Although the problem of sand erosion cannot fundamentally be eliminated, therefore considering sand erosion of blade is extremely important. In order to optimize the comprehensive, objective and accurate understanding of the sand erosion wear, we designed a set of erosion wear simulation experiments and used PLC and touch screen to realize quantitative control of sediment concentration in the erosion wear process. And it plays an important role in the effective protection of fan blades.

2. THE STRUCTURE AND WORKING PRINCIPLE OF THE SEDIMENT CONTROL SYSTEM

In the sediment control system, the sand in the sandbox flows evenly and vertically from the sandbox mouth, and then distributed by sand trap. The concrete position of sand plate is determined by the control system. PLC, as the core of the control system, controls the rotation of stepper motor, while the feed screw driven by stepper motor determines the location of the sand plate, and then builds the relationship of sand amount with the position of sand plate. PLC pulse output signal is used to accurately control the stepper motor's revolutions, and the flowing sand amount; the modification of sand amount is done by touch screen. The system chooses the grains of sand from the KuBuQi desert in Ordos city of Inner Mongolia. The working principle of system is shown in Fig. (1).

Due to a comparatively small amount of feed sand, it also requires sand trap mobile at small distance per minute, where the torque angle of stepper motor is 0.9° , so for every 400 pulse number of stepper motor rotating for a week, and the PLC sends a pulse signal to drive the feed screw moving at a distance:

$$S = \frac{\text{the pitch of feed screw}}{\text{the pulse number of stepper motor rotating for a week}} \quad (1)$$

It gets the calculation:

$$S = \frac{3}{400} = 0.0075mm \quad (2)$$

The PLC sends a pulse signal to drive the feed screw moving at 0.0075mm distance, which satisfies the accuracy requirement of this experiment.

3. HARDWARE DESIGN OF THE SEDIMENT CONTROL SYSTEM

PLC has several characteristics such as: high reliability, strong adaptability to the environment, flexible and general, easy to use and simple maintenance [2-4]. This control system chooses PLC of Siemens S7-200 series, the model is CPU224XP. The digital quantity input and output points of the controller are 14 and 10 respectively, and analog input and output points are 2 and 1 respectively. The program and data storage space is 20k bytes, it has two RS485 communication/programming ports, and can undertake PPI and MPI communication protocols. It has six independent high-speed counters and two high-speed pulses [5].

The frame design of touch screen replaces the original consoles and monitors, it not only extends the functionality of the PLC, but also reduces them to use as some instruments. And it has played an important role in the control system [6-10]. The touch screen chooses TPC7062K as its model, which constitutes 4-wire resistance touch screen, the system

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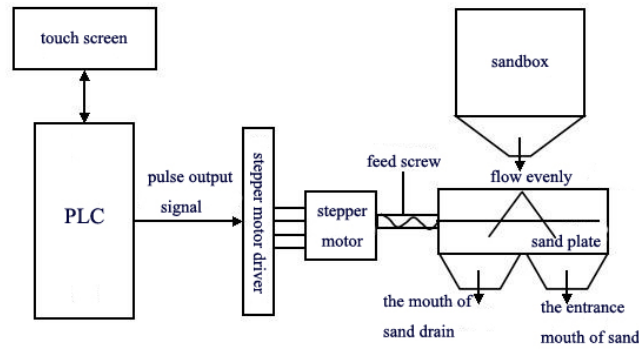


Fig. (1). Working principle of the sediment control system.

Table 1. 85BYG250A hybrid stepping motor parameter list.

Model: 85BYGH250A			
Phase Number	2/4	Inductance	3.4m.H
Torque angle	0.9°/1.8°	Maximum static moment	3.5N.m
Voltage	4.4	Current	4A

memory is 64M SDEAM, with a resolution of 800×480 high-definition images. And it supports RJ4/RS232/RS485 Ethernet communication interface.

The stepper motor drive chooses SJ-2H090MS, whose power supply for communication is AC (40V-60V) /3A or DC less than 80V/3A; the current is adjustable; can be divided into eight gears; and can also choose mono-pulse & dual-pulse and subdividing number. It drives with anti-jamming, high frequency, and good performance. It also has simple structure, smooth operation and low noise.

The greatest characteristic of stepping motor is digital. When the control system sends a pulse signal, stepper motor rotates at a fixed angle. Because we can control displacement through pulse number as this system chooses two-phase hybrid stepping motor 85BYGH250A, so it is widely used in various kinds of control systems [11-13]. Its technical data is shown in Table 1.

4. THE SOFTWARE DESIGN OF SEDIMENT COMC-CONTROL SYSTEM

4.1. PLC Program Design

The programming language of S7-200 is STEP7, and it can use ladder diagram and statement list for off-line programming. After compiling well, it can be directly downloaded to the PLC. When debugging the program, the working state of each input and output points can be monitored online. If found errors, you can also modify the program variables online. Through analysis and calculation, the process of sediment control system is shown in Fig. (2).

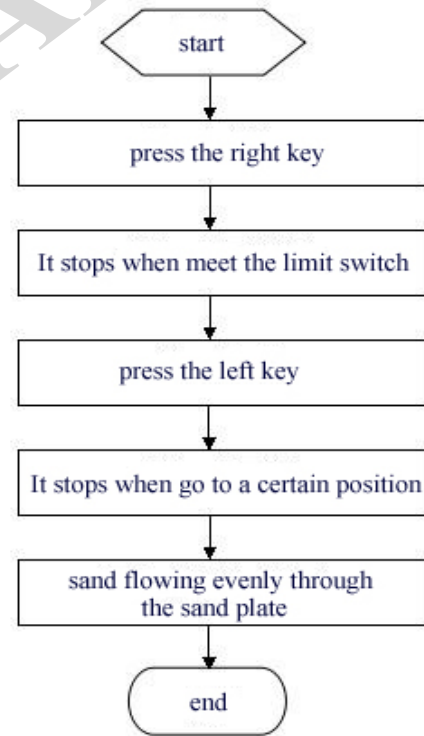
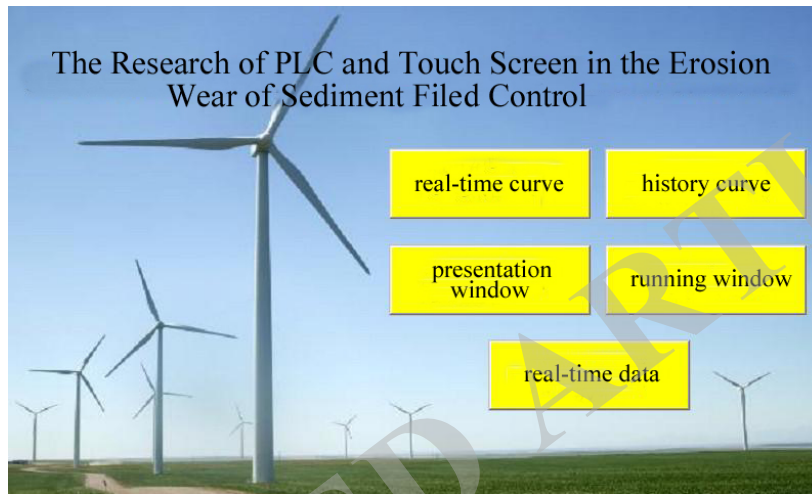


Fig. (2). The flow chart of sediment control system.

Although PLC used in this study provides the input point and its address is fixed, it can be extended according to the requirements of the experiment. The input/output condition

Table 2. The control system I/O port distribution table.

Input		Output	
I0.4	Start key of stepper motor rotating in forward	Q0.0	Pulse output
I0.5	Start key of stepper motor rotating inversely		
I0.6	Limit switch key	Q0.4	Stepper motor rotation
I0.7	Stop key of stepper motor		

**Fig. (3).** Main menu.

of the sediment control system in this experiment is shown in Table 2. In this control system, the stepper motor rotates on forward, inversely or stop keys, and its limit switch are controlled by switch value. We need to use three switch inputs that are stepper motor rotating in forward, inversely or stop and one limit switch input. And the two switch outputs are pulse output contactor and stepper motor reversing contactor. So, the input/output ports are 4/2 respectively.

4.2. The Software Design of Touch Screen

The touch screen program designed by the embedded version of the configured software MCGS7.6; MCGS embedded system structure is divided into three parts: the configuration environment, simulation running environment and running environment. Configuration and simulation running environment are equivalent to a complete set of tools, which can run on the PC. It helps users to design and construct their own configuration engineering and carry on functional test. The user application system is generated by MCGS embedded version. It contains five structures, including the main control window, device window, users window, real-time database and the operation strategy [14-16].

According to the requirement of the sediment control system, the configuration screen is designed as below.

4.2.1. The Main Menu Design

The main menu design mainly includes a few main screens, through designing the main menu we can choose or switch each screen, every screen can directly open into the window when press the button, so it is very convenient for users. The main menu is shown in Fig. (3).

4.2.2. Design the Running Window

The running window can simulate the current state, and it has stepper motor rotating forward, inverse, and stop keys. Every key has a corresponding indicator light. When the stepper motor rotates in forward, sand flow from leaking sand mouth. And when the stepper motor rotates inversely, sand flow from the entrance and leakage mouth, the indicator light on the stepper motor will prompt users. The running window is shown in Fig. (4).

4.2.3. Design the Demonstration Window

The demonstration window can change the data at any time according to the requirements of the experiment. The sediment control system is equipped with the sand plate left key, sand plate right key and stop key of stepper motor, it is convenient to control the system, and it also reduces some

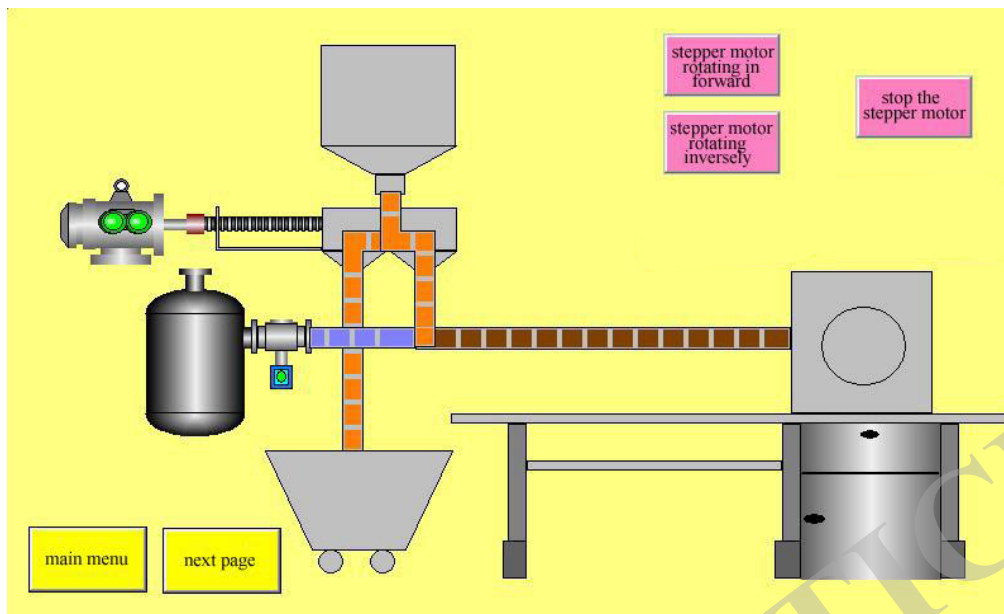


Fig. (4). The flow chart of sediment control system.

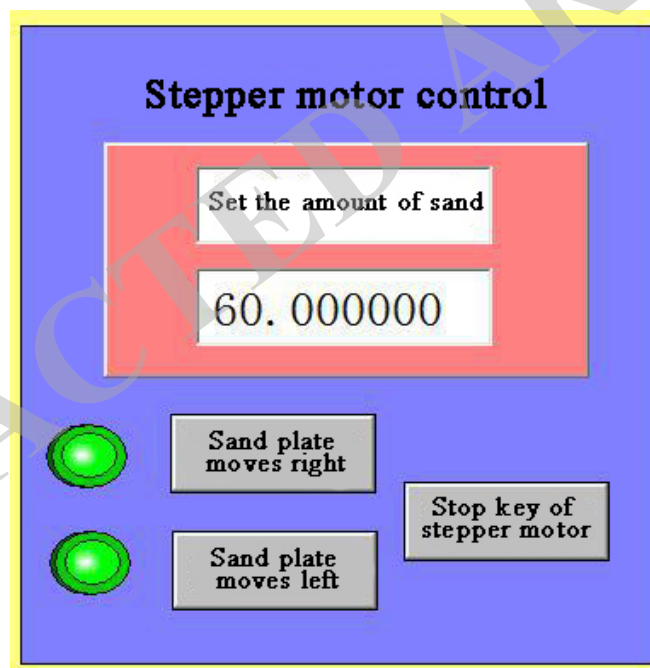


Fig. (5). Demonstration window.

experimental equipment. We set up a small light in front of the button, when the button be operated, the corresponding small light will flash, it can not only draw the operators' attention but also looks beautiful. The demonstration window is shown in Fig. (5).

4.2.4. Design the Real-time Data

The real-time data reflects the current data. It needs to not only consider the experiment control system data, but also set the current time and running time. And experiment-

ers can record the experiment data conveniently. The Real-time data is shown in Fig. (6).

4.3. The Communication Between PLC, Touch Screen and PC

This control system uses RS485 serial communication line between PLC and touch screen, the high transfer rate can be up to 20 KB/s, furthest distance is 15 m. Between touch screen and the upper machine the cable connection is composed of RJ45, and the transmission rate is about 10 Mb/s. When the

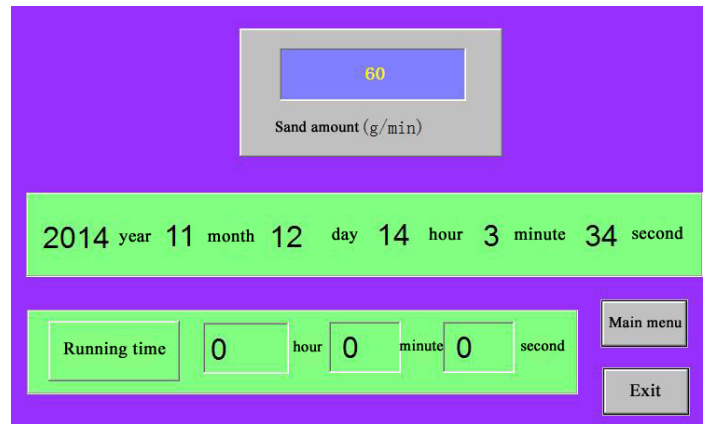


Fig. (6). The real-time data.

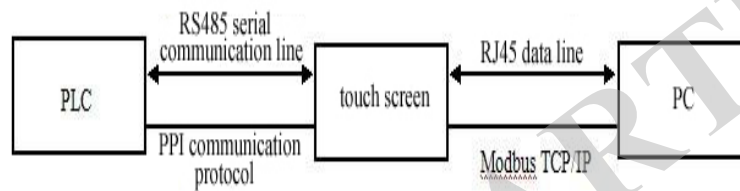


Fig. (7). The communication between PLC, touch screen and PC the real-time data.

Table 3. Sediment change table.

Impulse Number Output by PLC	Sand Amount (g/min)	Impulse Number Output by PLC	Sand Amount (g/min)
2000	1.25	2900	120.25
2100	2.83	3000	141.45
2200	6.18	3100	156.04
2300	13.06	3200	167.23
2400	24.50	3300	177.73
2500	38.40	3400	182.41
2600	56.37	3500	187.01
2700	79.16	3600	190.59
2800	99.88		

rate is lower than 100 KB/s, the transmission distance can reach 1200 m. Between each other it adopts PPI and the Modbus TCP/IP communication protocol, which is shown in Fig. (7).

5. ANALYSIS OF THE SEDIMENT CONTROL SYSTEM EXPERIMENT

This control system adopts open-loop control, where the stepper motor is controlled by PLC pulse output signal, so as

to control the displacement of sand plate, and it can finally realize the control of sand amount.

Moving the sand plate to the left of sand mouth, through this experiment, when the stepper motor turns 7.5 circles, the PLC outputs 2000 pulses, and the entrance mouth of sand starts to flow. Since then, adding 100 pulses every time, measures the flowing sand quantity, take average of all experimental data, records them in the table and finally draws a curve. The sediment change is shown in Table 3 and Fig. (8).

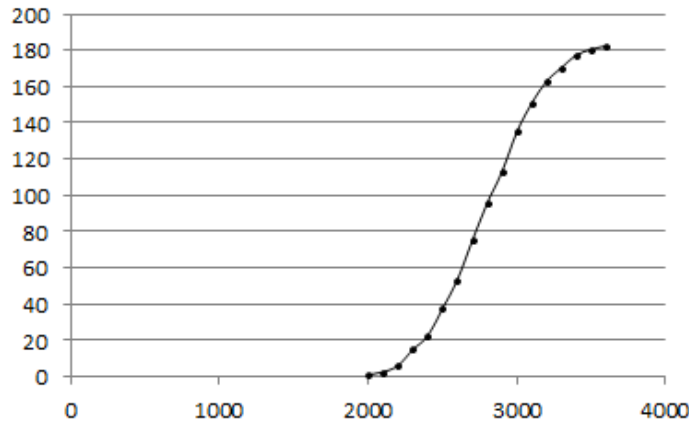


Fig. (8). Sediment variation.

Table 4. Experimental calculation data sheet.

Sand Amount (g/min)	Displacement of Sand Plate (mm)	Pulse Number Output by PLC
60	19.57	2609
70	19.97	2662
80	20.37	2716
90	20.77	2769
100	21.17	2823
110	21.59	2876
120	21.97	2929

In this range of sand flow quantity, when the PLC outputs 2000 pulses, the entrance mouth begins to inflow sand. When the PLC outputs 3600 pulses, all the sand flows into the mouth. In this process, the sand trap moved 12 mm, the total amount of sand is 190.59g. At the beginning and end of the experiment, the sediment changes a little, the middle section can be approximated to linear growth.

Taking a certain value of the amount of sand, we set seven sets of data by the touch screen, that is 60, 70, 80, 70, 100, 110, 120 g/min respectively. After calculation, we get the displacement of sand plate and the pulse number output by PLC. The information is shown in Table 4.

Through analyzing a series of experiments, the following conclusion is drawn: when the sandbox has enough sand, ensure that the sandbox board is set to a fixed position. The pulse output by the PLC controller is directly proportional to the displacement of sand plate, it is also directly proportional to the amount of sand in the entrance mouth. There is a certain relationship between these three values.

Through the experiment, we summarized the relationship of sand amount, sand trap displacement and the pulse number sent by PLC. During the experiment, we found the relationship of these three values and verify it through a series of

experiments. Experiments show that there is a certain amount of difference between the experimental data and the calculated values obtained. The main reasons for the error are as follows:

1. When the stepper motor is working it will lead to sand plate slight vibration, and the vibration can make the total sand amount flow from sandbox change.
2. The natural wind environment also plays a very important role in the experiment. And there is a short distance between the sandbox and sand plate. If the wind blows, it could lead to sand without flowing through sand plate and directly blow it into the sand mouth.
3. If the weather is wet, it likely to lead to mutual adhesion between the sand and results in a certain amount of error. But these factors influencing the experimental data are very small, and can be negligible.

CONCLUSION

By applying PLC and touch screen in the sediment control system, this control system simulates the quantitative sediment control of the fan blade erosion wear in the wind environment and realizes the sediment control in all ranges. The whole test system with high precision and accurate con-

trol, has important guiding significance on the further research of fan blade abrasion.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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