Design of the remote-control system for PM2.5 capture device

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Abstract: PM2.5 is the main factor of haze formation. This paper designed a remote control system for PM2.5 capture device by using combined strategies, which were redundant structure, acoustic vibration and reverse blowing. The remote control system is composed of Siemens PLC s7-200 series CPU, software and hardware. The system was simulated by Siemens S7200 SIM programming. The combined strategies realized the continues work. In addition, remote monitoring of the PLC control system implemented to make remote operation more convenient.

1. Introduction
The "grey haze" atmospheric phenomenon occurred in most cities in northern China in 2013. It was caused by the massive emission of PM2.5. PM2.5 refers to the equivalent diameter of less than or equal to 2.5 microns of particulate matter, also known as inhalable lung particles. Its less than 1/20 of the diameter of a human hair, permeate the air, scattering and absorbing visible light, reducing atmospheric visibility and affecting traffic safety [1,2]. In addition, PM2.5 has a small particle size and strong adsorption ability, which can be used as a "carrier" for many pollutants, viruses and bacteria, and stay in the atmosphere for a long time and transport over a long distance, seriously affecting the air quality. The problem of existing capture devices for PM2.5 is that the flux would decrease after working for a period. The reason is that partly PM2.5 adheres to the separated components [3,4]. In this paper, the s7-200 programmable controller from Siemens was selected as the controller of the capture device. The combined strategies, the redundant structure of PM2.5 capture device, acoustic vibration and reverse blowing, were used to realize the continuous operation of the capture device.

2. Working principle and control requirements of PM2.5 capture device

2.1 Working principle of PM2.5 capture device
PM2.5 were captured on the surface of the separated components through the delivery of the blower. Clean gas passed through the separated components, and PM2.5 was discharged with the gravity when the capture device stopped. Part of the PM2.5 adhered on the surface of the component layer, the internal channel was blocked with the increase of thickness, the pressured drop of components on both sides increased; The rate of passing clean gas were reduced, the pressure drop increases. It is difficult to make the adhesion layer fall off by using reverse blowing alone. With the increasing frequency of repeated reverse blowing, the initial flux was down. The paper proposed a combined strategies, redundant device structure; acoustic vibration and reverse blowing. First, the attached layers were destroyed by acoustic vibration, then reverse blowing is carried out. When one device is cleaned, the other device still works. As shown in Fig. 1.1 The redundant structure of PM2.5 capture device.

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consists of two PM2.5 capture devices. Each device contains the inlet valve (11), the outlet valve (13), draught pan (1), discharging valve (17), differential gauge (9), separation components (24), back-flushing valve (5), acoustic vibration valve (20), acoustic vibration generator (19), container of high pressure gas (39).

This process included 3 steps: first, the inlet valve (11) and outlet valve (13) were closed, when the differential pressure reached the specified value; second, the acoustic vibration valve (20) was opened, which drove the acoustic vibration generator (19); then the back-flushing inlet valve (5) and back-flushing outlet valve (7) were opened, after the structure of attachment layer was broken. The differential pressure is difficult to reach the specified value simultaneously, the redundant structure can carry out PM2.5 removal continuously.

![Fig. 1 The redundant structure for PM2.5 capture device](image)

2.2 Control requirements
(1) Normal: We set different working time. 10 min for device 1 and 11 min for device 2. That’s to say, draught fan (1), inlet valve (11) and outlet valve (13) of device 1 were opened and work for 10 minutes. draught fan (2), inlet valve (12) and outlet valve (14) of device 2 were opened and work for 11 minutes.

(2) Acoustic vibration: At the end of work, inlet valves (11) (12) and outlet valve (13) (14) were closed. Acoustic vibration valve (20) (21) were opened for 15 seconds.

(3) Back-flushing: (5) (6) the back-flushing inlet valve, (7) (8) back-flushing outlet valve were opened for 14 seconds.

(4) Discharging: (17) or (18) discharging valve were opened for 5 sec seperately, when the level switch (15) or (16) got the set point: if the device is normal, inlet valves (11) or (12) and outlet valve (13)
or (14); if the device is back-flushing, (5) or (6) the back-flushing inlet valve and (7) or (8) back-flushing outlet valve were closed. The program flow chart was shown in Fig. 2.

Fig. 2 The program flow chart
3. PLC control system design

3.1 Hardware Selection

The hardware includes solenoid valve, differential pressure meter, draught fan, acoustic vibration generator, level switch, PLC s7-200 series CPU. CPU226 with 24 input points, 16 output points and expanding module EM231, as shown in Fig.3, I0.0 ~ I0.6 as input, which is suitable for fault switch, I0.1 I0.0 for remote start switch, I0.2 start switch at site, I0.3 for remote stop switch I0.4 stop switch, I0.5 at site for level switch (15), I0.6 for level switch (16). Q0.0~Q0.7 and Q1.0~Q1.7 are outputs. Including Q0.0 for draught fan (1), Q0.1 for draught fan (2), Q0.2 for (11), Q0.3 for (12), Q0.4 for (5), Q0.5 for (6), Q0.6 for outlet valve (13), Q0.7 for (14). Q1.0 for the back-flushing inlet valve (5), Q1.1 for (6), Q1.2 for back-flushing outlet valve (7), Q1.3 for back-flushing outlet valve (8), Q1.4 for discharging valve (17), Q1.5 for discharging valve (18), Q1.6 for valve (20) Q1.7 for valve (20).I0.0 and I0.3~I0.6 are normally closed(NC) switches, and I0.1 and I0.2 are normally open(NO) switches.

3.2 Software Design and Simulation

This system adopts PLC s7-200 series of special step-7 MICRO/WIN software for programming. First, the ladder diagram is used to write the logical sequence of the automatic control system. Run s7-200 series of special simulation software "s7-200 Chinese version" for simulation, enter the simulation software, configure CPU226 and two EM231 analog input modules, and select the analog input current value of 0~20mA.Manually adjust the input parameters of the analog quantity in the normal state and load the programmed ladder diagram into the simulator.

The remote control system was realized through 2 steps: communication; PLC remote control. After connecting the computer and PLC with PPI line, run STEP7 programming software, select...
"communication" and then select "set PG/PC interface", and then set baud rate (generally 9.6kbit/s), and the point-to-point connection between the computer and CPU is completed. Run PC Access software, right mouse click on PLC to set "properties", to ensure that the IP address and TSAP address in PC Access should correspond to the figure above, for example, here we will set the IP address in PC Access to 192.168.0.8, local TSAP address to 11.00, remote TSAP address to 10.00, can complete the Ethernet Settings. Due to the limitation of distance, Ethernet cannot reach a relatively long distance. At this time, we can set up the CPU Internet through CP 243-1 IT module. The setting method is similar to the above Ethernet, but the connection through the Internet can realize ultra-remote monitoring and control of PLC anywhere on earth. After PLC communication is set up, the running state of PLC can be monitored and controlled remotely. For monitoring, OPC Server software -- PC Access as described above -- is needed. Run PC Access, create a new PM2.5 capture device, create a new folder "analog quantity monitoring" to create the six analog quantities required by the device, and make the address (VD0, etc.) correspond to the ladder diagram one to one. Access select RW, that is, read and write, but PC Access software can only read parameters, not write. So there is another need for a reading and writing software, in order to achieve the system of super remote control. We can use the PLC plug-in in EXCEL for reading and writing editing. Open EXCEL, load a "OPCS7200EXCELADDIN" control in the development tools editor, as shown in the figure below, and there will be four tool ids in the custom toolbar. This is the EXCEL control we need to use.

Enter the address and switch name in the cell. Reads the state of the remote boot switch into the location of cell C2 through the add-in's tool. The remaining switch quantities are also filled in the cell of state column in the same order as above. Since the running tool has not been opened yet, the status bar displays the #N/A flag. When the third tool of the load item is pressed, the status bar will display the parameters of the corresponding address in the working state of PLC. At this time, the operation of reading in data is completed and the purpose of remote monitoring is achieved. To achieve remote control, use the second write tool of the add-in. Press the write tool to rewrite the data VD0 of the corresponding cell into a value of 16.9.

4. Results
Start the PLC, open remote start I0.1 and on-site start I0.2, and the system starts to run with electricity, and the draught fan works. The inlet and outlet valves of the left and right two dust removal devices are opened, and then disconnect the I0.1 and I0.2 systems without power off, because a self-locking circuit is formed. When PM2.5 was collected for 10 minutes, the device started to vibrate and device 2 continues to dust. After 15 seconds of acoustic vibration and 14 seconds of back flushing, the device started again. When the pressure differential meter reaches the specified value (manually adjust the AIW2 analog value), device 2 is performing 15-second acoustic vibration, while device 1 continues to dust. At this time, if the pressure difference still fails to return to a normal level after one round of acoustic vibration and back flushing, the system will not carry out normal dust removal, but carry out the second or even the third round of acoustic vibration and blowing, until the membrane flux returns to make the pressure difference within the separation component reach a normal level.

When the ash particle reaches the position of material level switch (1), the material level switch I0.5 is energized, the ash discharge valve (1) is opened for ash discharge, and the ash discharge valve (1) is closed after 5 seconds, and the equipment starts to dust normally once again. When the ash particle reaches the position of the material level switch (ii), the material level switch I0.6 is energized, the ash discharge valve (ii) is opened for ash discharge, and the ash discharge valve (ii) is closed after 5 seconds, and the equipment ii starts to dust normally.

When the circuit fails, the whole system stops running. Or press the remote stop button or the field stop button, and the system will stop running.

At this point, the simulation is finished and the logic of the programming ladder diagram run normally.
5. conclusion
The remote control system was designed for PM2.5 capture device. The redundancy structure of device design can realize continuous uninterrupted operation, with Siemens S7-200 series, 226 type of CPU a shaker automatic control system, and according to the process of flow chart, the ladder diagram, the simulation process can be complete and correct. Through TCP/IP Internet protocol, remote monitoring and control of the whole system can be realized. Due to the limited experimental conditions, many industrial actual production conditions cannot be simulated, so if it is used in actual production, it needs to be adjusted according to the actual situation. This system realizes more intelligent and humanized design, reduces the labor intensity of workers, and makes the control of the whole system more convenient and faster.

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