ICESP X – Australia 2006
Paper 6B4

THE RECTANGULAR CONTROLLING PRINCIPLE AND METHOD OF AUTOMATIC FOLLOWING CONTROL ON DUST DENSITY IN ELECTROSTATIC DUST PRECIPITATION

ZHAO FU[1], HE JIAN[1], YU WENHAI [1] AND WANG MEIJU[2]

1. Automation Research Institute of Shijiazhuang City
No 452 Zhongshan East Road, Shijiazhuang City, 050031, China
2. Electric Power Plant Design and Research Institute of Hebei Province
No 6 Jianhua North Road, Shijiazhuang City, 050031, China

ABSTRACT
This article describes the principle and method of automatic following control on dust density in electrostatic dust precipitation (ESP) that is based on the changing law of dust density in ESP electric field and uses automatic adjustment of output voltage. Rectangular load characteristics for high-voltage power supply source is formed on which the work point located in the vertical line. When dust density changes the work point will timely rises or falls along the vertical line. Experience shows that this method is very simple, efficient and energy saving though there is no special on-line monitoring and control measures used on dust density.

1. INTRODUCTION

Due to technical difficulties in real-time measuring on actual value of dust density, especially the reliability of these measures in complicated on-line conditions most electrostatic ESP systems are not fitted with real-time measuring and automatic following control on density of dust emission. As a result manual adjustment of power supply voltage based on previous experience is used to maintain an expected density value of dust emission. Meanwhile this brings some practical problems as follows:

1.1 It is impossible to realize manual real-time observation and control on standard dust discharge in the changing dust precipitation electric field.

1.2 To suit a wider entry density range system in a “higher control surplus” condition comparing with standard discharge value. This means that the system will run at full power ignoring dust quantity. We call this phenomenon “A Big Horse Pulling a Small Cart” which will be waste a large amount of electric energy.

1.3 More labor burden for workers.

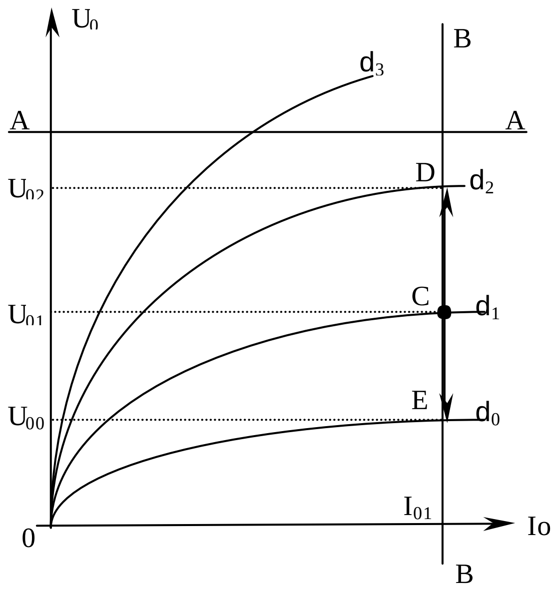
To solve these problems this article provides the working principle and method of automatic following control on dust density in electrostatic dust precipitation. What is more important is that this method is very simple, efficient and energy-saving though there is no special on-line monitoring and control measures used on dust density.

2. PRINCIPLE OF AUTOMATIC FOLLOWING CONTROL ON DUST DENSITY

See figure 1

Figure 1

U_0—power supply voltage in electric field
I_0—power supply current in electric field
AA— control line for U_0, horizontal, vertically adjustable
BB—control line for I_0, vertical, horizontally adjustable
d — load curve of different dust density, where $d_0 < d_1 < d_2 < d_3$



Obviously load curves of power supply characteristics form a rectangle surrounded by straight lines AA and BB in Figure 1.This is the precondition for the following analysis. Let us suppose that power voltage control line AA is horizontal setting at the maximum permissible value that is jointly determined by safety and reliability of dust precipitation system based on practical experience. Suppose the dust density in electric filed based on experience or actual measurement is d_1 now adjust current control line BB to working point C and the corresponding power supply voltage U_{01} and current I_{01} happen to meet requirement for dust discharge.

When the actual dust density d in the electric field increases as d_1 to d_2 shown in Figure 1 the actual working point C will surely slide to D along the vertical line BB thus raising voltage to U_{02} in the rectangular characteristics of power supply. Because $U_{01} < U_{02}$ the electric field intensity increases and accordingly the dust removing ability also is strengthened thus the density of dust discharge value being maintained at preset value.

On the contrary, when the actual dust density d in the electric field decreases as d_1 to d_0 shown in Figure 1, the working point C will timely slide to E along the vertical line BB thus reducing voltage to U_{00}.

We can clearly see that U_0 changes when dust density d changes and this process is determined by the rectangular load characteristics of power supply and load characteristics of dust precipitator. We call this process the rectangular automatic following control on dust density or simply the "Rectangular Control Method" for dust density automatic following control.

3. NECESSITY OF RECTANGULAR CHARACTERISTICS

Obviously the rectangular characteristic method described above cannot be manually adjusted in routine operation due to the objectiveness of the load characteristics of dust precipitator (except the adjustment of dust precipitator). Then the forming of an ideal power supply for rectangular control is another key technical problem.

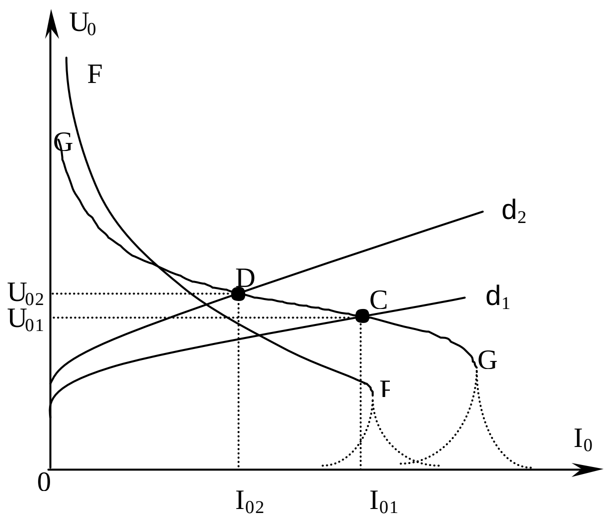


Figure 2

Normally most of the output load characteristics of special dust removing power supply in actual practice is a kind of natural external characteristics as are shown in Figure 2 where FF curve is the external characteristics of high frequency inversion power supply, GG is external characteristics of ordinary alternative rectified power supply. Other power supply of current limiting type often works in a certain saturated or stop status as shown by the dashed line on the right in Figure 2. Automatic dust density following control directly using the above method often fails to meet requirement for standard of the fast changing dust density in wide-range.

Suppose ordinary alternative rectified power supply is used and the output load characteristics is described as GG in Figure 2 and its working point is C, corresponding work voltage is U_{01}.When dust density in electric field rises

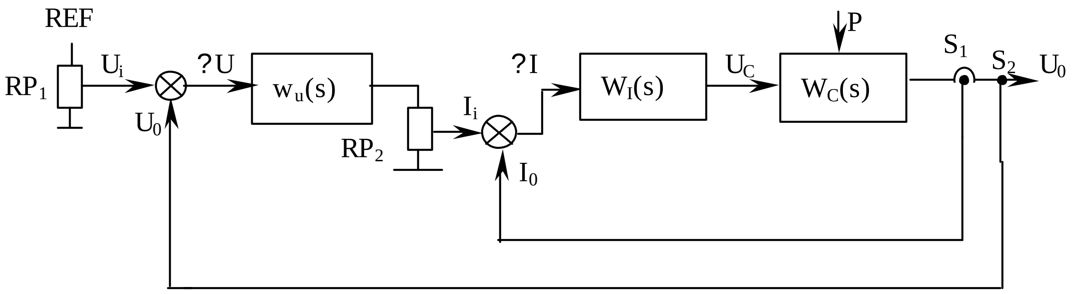


Figure 3

to d2 the variation of output high voltage compared with Figure 1 is much smaller. Therefore, the automatic following control on dust density is very weak and has no practical controlling significance. Similarly when dust density reduces the fallen value of high voltage is also smaller and has no energy-saving significance.

As for use of ordinary high frequency inversion power supply the external characteristics is soft compared with AC rectified power shown by FF either fails to achieve efficient following result.

We see that it is necessary to form rectangular load characteristics on power supply if we want to accomplish automatic following control on dust density.

4. METHOD OF FORMING RECTAN- GULAR CHARACTERISTICS

Figure 3 shows the principle of form- ing ideal rectangular load characteristics for power supply current. where $W_U(s)$refers to the adjustor for load voltage U_0, $W_I(s)$refers to the adjustor for load current I_0, $W_C(s)$ refers to the power controller and S_1 refers to the sampler for load current I_0, S_2 refers to the sampler for load voltage U_0 , RP_1 refers to the control point adjustment for load voltage , RP_2 refers to the control point adjustment for load current.

The following is the work principle of the system.

Get load voltage control point U_i by adjusting RP_1 and get algebraic sum through U_0 from S_2. Then the deviation is achieved.

$$\Delta U = U_i - U_0 \qquad (1)$$

The deviation after $W_U(s)$ produces PID contained controlled variable which is separated voltage released by current control point adjustment to get load current given value I_i. Work out deviation ? I through I_0 from S_1.

$$\Delta I = I_i - I_0 \qquad (2)$$

The deviation after $W_I(s)$ produces PID contained controlled variable U_c which motivates power controller $W_C(s)$ to produce load voltage U_0 and load current I_0.

Please note that so long as $W_U(s)$ and $W_I(s)$ are designed as isochronous adjustors the system shown in Figure 3 will be a steady and isochronous automatic controlling system. At this time the following formula come into existence:

$$\Delta U = U_i - U_0 = 0 \text{ , viz. } U_i = U_0 \qquad (3)$$

$$\Delta I = I_i - I_0 = 0 \text{ , viz. } I_i = I_0 \qquad (4)$$

Formula (3) shows that if U_i is fixed as an invariant then U_0 will not be affected by I_0, in other words the voltage control line AA in Figure 1 is formed as a horizontal straight line parallel to I_0.

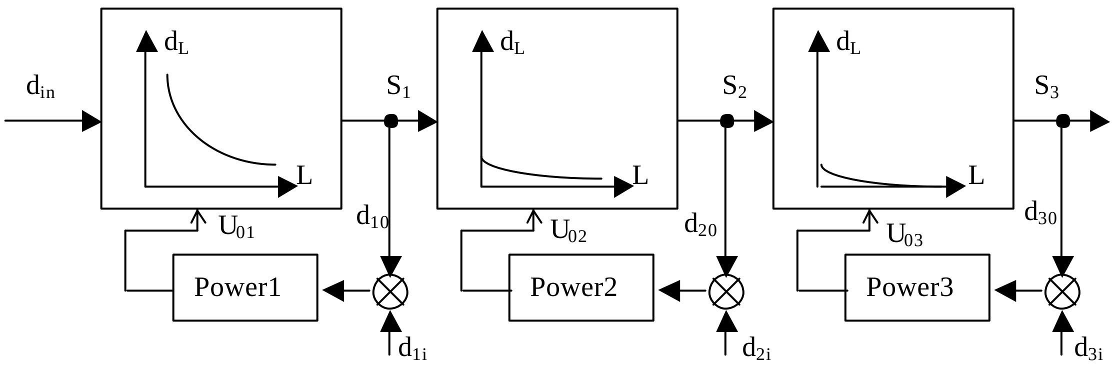


Figure 4 Principle of Conventional Automatic Following Control on Dust Density

Similarly formula (4) shows that output current value I_0 is not affected by U_0 when system is in steady status. Current control line BB shown in Figure 1 is formed as a straight line vertical to axle I_0.

Accordingly the rectangular load characteristics required by automatic following control on

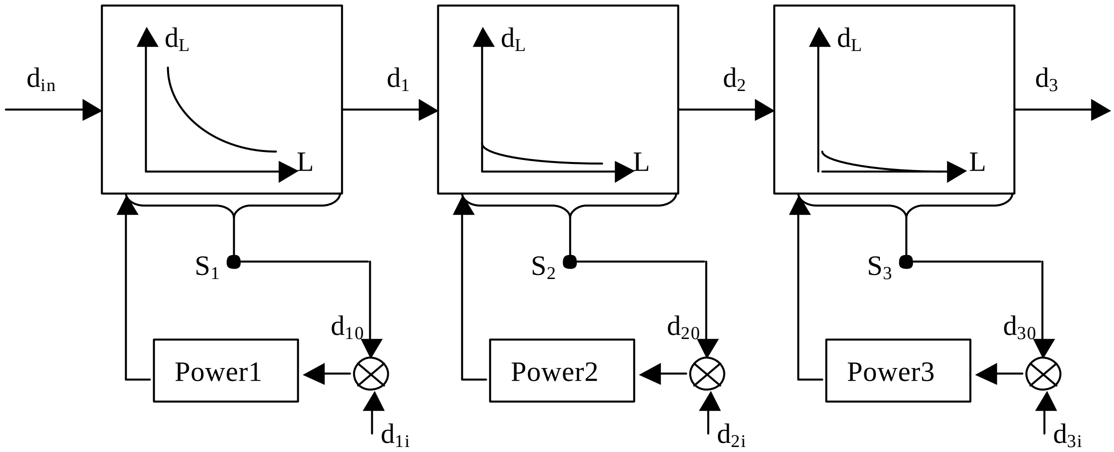


Figure 5 Principle of Rectangular Automatic Following Control on Dust Density

dust density described above can be achieved by use of the system shown in Figure 3.Position of horizontal straight line AA can be easily fixed by adjusting RP_1 and the position of vertical straight line BB can be easily fixed by adjusting RP_2 to suit requirement of different electric field condition. Automatic following control on dust density is accomplished in this way.

5. MAIN ADVANTAGES OF RECTAN- GULAR CONTROL METHOD

5.1 Real time control

As shown in Figure 4 most conventional dust density following control systems use discharge density d_{out} feedback automatic control system. In the figure d_L-L refers the layout of dust density d_L while distance between dust precipitator and entry L constantly increases. Power supply controlled quantity U_0 is formed only discharge density d_{out} is measured at exit of dust precipitator so as the maintain an unchanged discharge density. As time for d_{out} measurement is longer than dust passing in each electric field L. The fluctuation margin of d_{out} is big. Therefore the system lacks high quality of real time control.

As is shown in Figure 5 rectangular control method is different from conventional feedback control in the way that it adjusts voltage according to real-time dust density measured in electric field. Electric field load characteristics can timely reflect dust density once dusts appear in the range of electric field length L. In other words, the rectangular control method forms the “dust density measuring” space within the whole range of electric field L rather than measuring it only at the discharge exit. Moreover, all dust density changing value within this range can be immediately reflected by load characteristics curves of the dust precipitator. Therefore, rectangular control method is a feedforward control system with outstanding real-time following property. This control system has a limited time delay and is much better than conventional feedback control system in terms of instantaneity.

5.2 Simplicity in system structure

Because no special on-line dust density measuring facility is used in this method there is no need to spend money on protection facilities such as dust accumula- tion prevention, anti-clogging, prevention of condensation of moisture, prevention of high temperature and interference prevention. Accordingly there is no need for sensor installation and maintenance. So this simple following control system only requires the rectangular load characteristics of power supply current. Maintenance and applica- tion are very easy.

5.3 Power energy saving

Obviously the method is saving in electricity consumption. During the automatic following control process work is accomplished along vertical line BB and at this time the load current I_0 in electric field is an invariant. When dust density d rises working point C will slide upward thus raising supply voltage U_0. When $P_0=U_0$ I_0 will grow which is necessary for improvement of dust removing ability. On the contrary, when dust density d falls working point C will slide downward thus reducing supply voltage U_0. When $P_0=U_0$ I_0 will decrease. The reduced power equals to the saved electric energy during dust removing ability is reduced. It is worth mentioning that when dust source lays off, in other words when d is close to zero, U_0 will falls to a very low level thus saving a large amount of electric energy.

6. APPLICATION EFFECT

This rectangular control method has been successfully used in many electrostatic dust precipitators of ours. Applications show that this method is quite efficient in electrostatic dust precipitation for controlling and following the dust density.

Table 1 gives a site record of 80M2 electrostatic dust precipitator used in the sintering plant of a well-known iron and steel group in China. The F series high frequency power and high voltage supply manufactured by Automation Research Institute of Shijiazhuang City is used in this system. The output rectangular characteristics are formed using U_0 and I_0 dual closed loop error-free automatic control system shown in Figure 3.

Table 1

time sequence	1	2	3
active state of dust source	Fan is set off.	Air supply starts.	Normal air supply
field power supply voltage U_0 kV	-55	-90-100	-75

We observe that at the beginning stage2 of air supply the sudden appearance of strong blowing air raises large amount of dust that was accumulated in pipe and air channel. The density of these dusts is much higher than dust density in normal dust precipitation. That is why we find an immediate rise of U_0 from around 55KV to above 90KV. It will return to normal value around 75KV when dust peak passes.

Our practice shows that rectangular following control on dust density not only guarantee dust discharge quantity but also saves large amount of electric energy. It like that kills two birds with one stone.