

THE STUDY ON SIMULATION OF OPTIMIZE CONTROL SYSTEM FOR ELECTROSTATIC PRECIPITATOR

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ABSTRACT

The thesis hammered at the study on simulation of Economize on Energy & Optimize control system for Electrostatic Precipitator (ESP). To get the highest efficiency, namely the lowest dust discharging concentration, the software can automatically select different controlling style and electric-field characteristics according to different working stations. Based on simulation of distributed control system of ESP and a series of established mathematic models, the software can finally find best controlling style after a series of analyses. In the light of optimize control theory, this simulation software of Economize on Energy & Optimize control system for ESP was developed. The software can run independently on distributed control system of ESP. A large number of simulation experiments manifested what is followed: the simulation software have a good man-machine interface and simple operation; the expected goal of optimize control was achieved, at the same time energy was economized. It can make great importance and reference on development of ESP-control software and improvement of ESP power supply control.

INTRODUCTION

As environment protection equipment to remove dust and control air pollution, ESP is widely applied in many fields, such as electricity, metallurgy, building materials and chemical industry, etc. Newly promulgated standards for air pollution emissions set an even higher demand on the characteristics of ESP. Using computers to real-time track all kinds of ESP's parameters and automatically choose optimal control methods and characteristics are important way to enhance working performance of ESP.

Based on the mathematic simulation models which are established according to the optimized control theory, the authors developed economize on energy & optimize control system software for ESP. It can work independently in the distributed control system of ESP. Simulation experiments showed that the software has friendly interface, easily operating, and can achieve expected optimize control objectives and energy saving. It can make great importance and reference on development of ESP-control software and improvement of ESP power supply control.

ESP OPTIMIZE CONTROL SYSTEM

ESP optimize control system is developed from ESP distributed control system.

Basic functions of the system

- i) Host machine get all kinds of operating parameters and status information of ESP electric equipments from lower computer, including turbidity, temperature, pressure and other parameters closely related to ESP operation and management, providing basis for the energy efficiency and optimize control.
- ii) To high-voltage electricity supply equipments, it can real-time adjust current flow limit, spark frequency, and spark response characteristics etc, real-time test voltage, current and spark discharging instantaneous waveforms, test electric field dynamic volt-ampere characteristics curve, at last achieve distributed and optimize control of these equipments.
- iii) To low-voltage equipments, it can set beating procedures of system and chain relation, set beating height and frequency of electromagnetic beater, set controlling way and operating parameters of dust unloading and transporting system, set const-temperature control scope.

Optimize Control

Highest dust removal efficiency (that is, smallest discharging dust concentration) as optimize control objective, the software can automatically select different controlling style and different electric field characteristics according to different working stations. Based on simulation of distributed control system of ESP and a series of established mathematic models, the software can finally find best controlling style after a series of analyses.

- i) Peak voltage benefits to dust charging. Average voltage benefits to dust capture. So choosing different voltage waveform according to different dust ratio resistance has benefit to the dust charging and capture.
- ii) Through correct choice of impedance of high-voltage power supply equipments, with adjustment, reasonable impedance matching is achieved. At last, volt-ampere

characteristics of high-voltage power supply system improved, electronics corona current enhanced, so the goal of heighten efficiency is achieved.

- iii) According to different dust inlet concentrations and ratio resistance, the system adopts different high voltage power supply methods, at same time, properly adjusts voltage rising rates and spark frequency. This way, it can better improve power supply characteristics and heighten efficiency.
- iv) Through choosing reasonable beating procedures, ash unloading control and heat controlling way of insulator, dust removal efficiency can also be improved to some extent.

Energy Economizing Control

The dust removal efficiency of ESP is not completely corresponding to its power rate supply. Fixed power supply and control methods could not suit to the change of working condition, especially to low-load, low-ash and high-ratio resistance dust. Now adopting intermittent power supply way, it can get basically same efficiency with traditional whole-wave power supply and largely economize energy.

Energy economizing control takes the outlet dust concentration of ESP as controlling basis, to achieve the optimize goal of smallest energy consuming of ESP. When the inlet flue-gas dust concentration (C_i) is constant, using outlet flue-gas concentration (C_o) as exporting quantity, up-limited voltage of each electric field (U_{im}) as exporting conditions, the binding conditions of optimize is that outlet flue-gas concentration (C_o) is smaller than permission highest discharge concentration ($C_{o_{max}}$), to let total power consumption of each field trend to smallest.

SIMULATION MATHEMATIC MODELS OF ESP

In order to achieve optimize control of ESP, the thesis took ESP in 300MW coal-fired power plant as studying object, established a series of simulation mathematic models, part of them as following.

Working Conditions Models of ESP

Including inlet flue-gas quantity, dust concentration, temperature and pressure models, dust diameters and ratio resistance models etc.

$$Q_i = 200 \times 10^4 + Rnd_1$$

$$C_i = 20 + Rnd_2$$

$$p_i = 5 \times 10^{10 + Rnd_3}$$

In these formulas:

Q_i inlet flue-gas quantity (m^3/h);

C_i inlet flue-gas dust concentration (g/Nm^3);

p_i dust ratio resistance ($O \cdot cm$);

Rnd_1 Rnd_2 Rnd_3 random function.

Power Supply parameters Models of ESP

Including models of corona inception voltage, top-limited voltage, up-limited circuit, volt-ampere, heating system, beating system and ash unloading system controlling characteristics adjustment etc.

$$U_0 = aE_0(4b/pa)$$

$$E_0 = f \times [31.02d + 0.954(d/a)^{1/2}] \times 10^5$$

$$I = K \times U \times (U - U_0)$$

In these formulas:

- U_0 corona inception voltage (V);
- E_0 corona inception electric field strengths (V/m);
- I corona inception circuit (A);
- U working voltage (V);
- a smallest curvature radius of corona wires (m);
- b distance of different electrode (m);
- K volt-ampere coefficient;
- f coarse coefficient of corona wires, usual 0.85;
- d relative density of the gas, decided by the temperature and pressure of flue-gas.

Performance Parameters Models of ESP

Including models of each field's grade dust-removal efficient, total ideal efficient, total non-ideal efficient, outlet flue-gas dust concentration, flue-gas leaking quantity, working resistance, secondary blowing dust quantity etc.

$$n_i = [1 - e^{-(K_p \times U_i \times I_i / Q + w_i)}] \times 100\%$$

$$n_T = [1 - (1 - n_1)(1 - n_2)(1 - n_3)(1 - n_4)] \times 10$$

$$n_T' = K_c K_M K_s K_d \times n_T$$

$$C_o = (1 - n_T') \times C_i \times 10^3$$

In these formulas:

- n_i efficiency of the field of grade i ;
- n_T total ideal efficient;
- n_T' total non-ideal efficient;
- C_o outlet flue-gas dust concentration (mg/Nm³);
- U_i, I_i voltage and circuit of the field of grade i ;
- K_p electric power quality amended coefficient;
- Q flue-gas treatment quantity of ESP (m³/s);
- w_i natural subsidence efficiency amended coefficient of each field;
- K_c amended coefficient of blow-by flue-gas;
- K_M amended coefficient of secondary blowing dust;
- K_s amended coefficient of airstreams distributed homogeneity;
- K_d amended coefficient of dust particle average size.

SIMULATION SOFTWARE OF ECONOMIZE ON ENERGY & OPTIMIZE CONTROL SYSTEM FOR ESP

While developed, the software took Windows 2000 as operating system, Force-control V2.61 as developing platform. At last, it has been compiled to an installing tool-bag and can run independently in Windows system.

Design Concepts of the Software

The software design mainly considers following.

- i) It can embody architecture of the distributed control system of ESP.
- ii) Having good human-machine interface, visual and simple surveillance operation.
- iii) Having good adaptability and expanding capability, to fulfill different working conditions and entity structure, easy to future developing.

Functions of the Software

- i) Dynamically imitate flue-gas state and flow in boiler, ESP entity and flue-gas transportation system, and imitate ash unloading flow etc.
- ii) Simulation control high-voltage power supply equipments. It can achieve the start and stop of system, switch between manual and automatic control, adjust high-voltage power supply controlling characteristics, and display voltage and circuit of each field stimulatingly.
- iii) Simulation control low-voltage controlling equipments, such as heater, beater, ash unloading etc.
- iv) Achieving economize on energy & optimize control of ESP. Dynamically real-time display flue-gas parameters and operating characteristics curve before and after control, working parameters of each field, dust removal efficiency, outlet flue-gas dust concentration and power economizing effect.
- v) History data storage and inquiry, parameters printing etc, monitoring and analyzing operating state, controlling characteristics and state of ESP in different time point or range.
- vi) Failure warning and diagnostic functions, providing common failure phenomenon and related analysis.

SIMULATION EXPERIMENT AND RESULT ANALYSIS

The authors made a series of simulation experiments. Contrasted the experimental data with actual, adjust and perfected the system over and over again, making it fit to the actual working state. Some simulation experiments effects are as following.

Simulation Experiment of Dust Ratio Resistance Influencing Dust Removal Efficiency

From Fig. 1 we can see, with the increasing of dust ratio resistance (p), dust removal efficiency (η) drops. When “ p ” is bigger than $10^{10} \text{O}\cdot\text{cm}$, “ η ” sharply drops, and outlet flue-gas dust concentration sharply increases. It results from the anti-electronics corona produced by the high ratio resistance dust.

Simulation Experiment of Inlet Flue-gas Quantity Influencing Dust Removal Efficiency

From Fig. 2 we can see, with the increasing of inlet flue-gas quantity (Q_i), outlet flue-gas dust concentration (C_o) increases, and dust removal efficiency (η) drops. When “ Q_i ” is bigger than $200 \times 10^4 \text{ m}^3/\text{h}$, “ η ” apparently drops. This is because of the shorter time of dust staying in the electric field.

Simulation Experiment of Economize on Energy & Optimize Control of ESP

When the maximum value is imported which ESP permits emissions concentration, economize energy control is started. The Table 1 shows the result of simulation experiments. In a longer period of time, the system can automatically change the status of all controlling parameters with the varying of working conditions. The average outlet dust concentration of ESP can maintain at a certain level to ensure emissions be up to the standard. And ESP can achieve economize energy purposes under operating in a state of saving energy.

CONCLUSIONS

Economize on energy & optimize control system for ESP has enormous economic potential and broad application prospects. It is believed to more widely apply. The thesis developed the simulation software of electrostatic precipitator's optimizing and controlling system. The software has friendly interface, easy operating, and achieved the expected goal of optimize and economize. It can make great importance and reference on the development of ESP-control software and simulation training.

Table 1: Simulation experiment effects of economize on energy & optimize control of ESP

Main Parameters		Before Control	After Control
Binding Conditions $C_{o(\max)}$ (mg/Nm^3)		None	200
Operating Time		1 hour	
Top-limited Working Voltage and Circuit Of Each Electric Field	U_{1m} (kV)	54.3	48.5
	U_{2m} (kV)	56.7	51.7
	U_{3m} (kV)	58.9	53.0
	U_{4m} (kV)	62.0	0
	I_{1m} (mA)	887	666
	I_{2m} (mA)	987	784
	I_{3m} (mA)	1084	835
	I_{4m} (mA)	1228	0
Fluctuation Range of C_o (mg/Nm^3)		20-145	65-170
Average C_o (mg/Nm^3)		82.5	117.5
Dust Removal Efficiency (%)		99.45	99.33
Total Electronics Corona Power P_c (kW)		244	117
Outlet Flue-gas turbidity (%)		18	22
Discharging Whether or Not Standard		yes	yes
Energy Economize Effect		None	52.05%

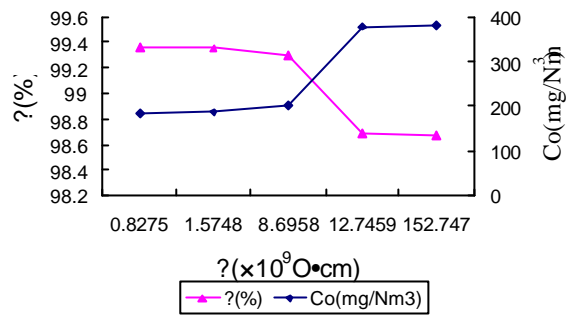


Figure 1: Dust ratio resistance simulation experiment curve

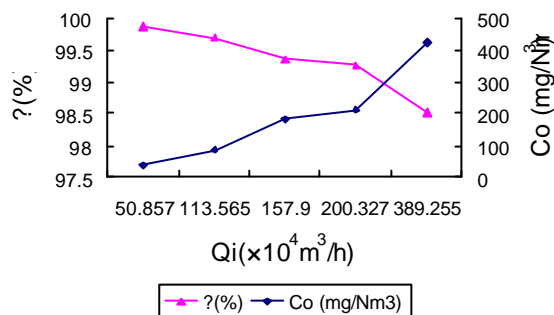


Figure 2: Inlet flue-gas quantity simulation experiment curve

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