The Development and Application of an Energy Saving System Based on the Optimal Control and Multi-parameter Feedback

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Abstract: The paper analyses the main issues and the key technologies which need to be solved of the electrostatic precipitator (ESP) energy saving control. On the basis of analyzing many ESP on-site operation data and the voltage-current curves, we developed a new type energy saving control system by combining a lot of ESP performance tests comparison and technologists' experiences. The new system is a closed-loop control system with multi-parameter feedback, and it has the functions of analyzing the ESP's working conditions accurately and adopting the optimal control by using the latest analysis software of the working conditions characteristics. The paper also introduces the field applications of this system.

Keywords: electrostatic precipitator (ESP), energy saving control, analyses of the working conditions characteristics, multi-parameter

1 BACKGROUND

With the development of the economy and the society, the shortage of energy sources has become a common problem facing the whole world. The policy of energy saving and emission reduction in our country has been deeply rooted among the people, which is being putted into action by every aspect now. The ESP plays an important part in the environmental protection, whose effect is to collect the dust efficiently and reduce the dust emission. However, the ESP will consume a lot of electricity energy when it works. The index of ESP's consuming energy has become an important technology parameter in the bid, and it is also an important aspect for the ESP users such as power plant to implement the policy of energy saving and emission reduction and to reduce the production cost.

2 SEVERAL MAIN ISSUES ABOUT THE ESP ENERGY SAVING

The high-voltage power supply equipments of the ESP are generally considered to be the main energy consumption ones. It may take as high as 80% both in the design capacities and the actual running power consumption of the ESP. Under the condition of satisfying the emission request, the ESP has the big potential to save more electricity, and the economic effect is obvious. This can be indicated by the researches and practices of many years.

At home and abroad, many ESP manufacturers have designed many kinds of high-voltage controller and monitoring control system of the ESP with the function of saving energy since 1990. Among these ESP manufacturers, Fujian Longking Co., Ltd. took the lead in developing the intelligent precipitator control system (IPC) with the function of EMS energy management independently in China. The IPC system bases on the mode of opacity closed-loop control, and it has been used for many years. In the mode of the energy management, the IPC system can transfer the software packages of energy management from the system automatically. And according to the feedback signal of the opacity, it can adjust dynamically the operation parameters and running levels of each high-voltage silicon rectifying equipment to the given values which can meet the demands of current dust removal effect and get the purpose of energy saving. Since the running of the ESP is dynamic, during the processes of the on-site debugging or the reality running, we can adjust the relevant control parameters about energy management in IPC system according to the actual situation to meet the demands of on-site operation better. The IPC system has been applied successfully by many consumers in the past 10 years, and gained a good effect.

Currently, there are still some issues in the actual application of the energy saving ESP, as follows:

(1) Most of the opacity meters which being used for a long time are in an abnormal state because of the bad use environment and the shortage of necessary upkeep. So the function of EMS energy management can't be used normally.

(2) The power plants often change their coal for the shortage of coal resources, which makes the working conditions characteristics of the ESP to vary in a large range. If we neither know the ESP performances which affected by the coal and the fly ash nor have the ESP analyses software to help us, we will not design the control system which can vary correctly by tracking the working conditions automatically. In this way, the system may save some energy, but the ESP efficiency is not high or even to discharge beyond standard gravely.

(3) The ESP is a complicated system with multiple parameters. It is pivotal for us to master the various important parameters which affect the working conditions characteristics and the performances of the ESP. We can choose a correct method by analyzing the potential of the ESP energy saving. It's a very urgent job for us to design an energy saving control

system which can meet the demand of energy saving and emission reduction efficiently. This energy saving control system is a closed-loop one with multi-parameter feedback, and it can guarantee the ESP to work in a good state.

3 RESEARCH AND DEVELOPMENT OF THE NEW TYPE ENERGY SAVING CONTROL SYSTEM

Generally, the potential of the ESP energy saving are incarnated in the following aspects: Firstly, the back corona will happen if the low sulfur coal whose fly ashes have the high resistivity is used. In this condition, the back corona maybe turn to be more severe and even cause the collection efficiency to drop if the power of high-voltage power supply is added. But the intermit pulse power supply can overcome the back corona which caused by the dusts with the high resistivity on some extent, and it also can save some energy and improve the collection efficiency. This can be certified by theories and practices. Secondly, it's a chance to save some energy when the load of the boiler changes. The drop of the load can cause the flue gas volume at ESP's inlet and the field gas velocity to fall and some energy can be saved by reducing the ESP's running power.

However, the ESP's running faces extremely complicated working conditions with the situation of the coal resources in China which is mentioned above. So in the design of the energy saving control system , we must think over many key factors which affect the collection efficiency, such as the kind of the boiler, the flue gas volume depending on the used coal, dust concentration, gas temperature, gas component, running and operation conditions, and so on. Therefore, the first key technology in development of the new type energy saving control ESP is to guarantee the collection efficiency under the complicated working conditions. In order to put it into details, we need to start with analyzing a large amount of data from the different coals, the different working conditions and the different loads. We also need to analyze the relations between the electric field's curve race (average value curve, peak value curve, valley value curve) and the changes of the working conditions characteristics. Then we can build a mathematic model of ESP's working conditions analysis software. The analysis software's output result can judge whether there is a back corona or not and differentiate the back corona (or the regular corona) from different ranks. Finally, we can summarize the relations between the working conditions and the optimum control mode according to a lot of on-site experiments and ESP technologists' experiences, and distribute the rational duty ratio of intermit power supply to each electric field. The second key technology in development of the new type energy saving control ESP is to change the feedback control signals from only opacity to many parameters of boiler load, opacity and the gas temperature etc. The new type energy saving control system will be developed basing on the analysis of the on-site working conditions. This system can guarantee the feedback system to work in a good state and save energy indeed. The third key technology is to use the compound power rapping technology and the high frequency power supply, which can save more energy.

In the past few years, we collected a lot of file data bases of Longking IPC systems which were running, and got many extremely important on-site testing data by doing a great quantity of on-site tests. After dealing with these data for many times through the methods of analyzing, summarizing, concluding and improving, we built a new mathematic model which can analyze the working conditions characteristics. The new mathematic model not only can judge whether the state of the electric field working conditions is in the back corona or in the regular corona, but also can differentiate the back corona (or the regular corona) from different ranks. The new model can calculate out the ESP's indexes of the back corona or the regular corona reliably, after doing that it can reflect the ESP's working conditions and change trend accurately. Then, it can choose the best running mode and energy saving mode for every electric field according to the experiment study results and industry application experiences. We can take two electric fields' voltage-current curves for instance, which are shown by Figs.1 and 2. The voltage-current curve of Fig. 1 indicates that there is a back corona in this electric field, whose back corona index is 46.4 (The bigger the back corona index is, the more severe the back corona is. The index 46.4 indicates that there is a back corona of middle degree); the voltage-current curve of Fig. 2 indicates that there isn't a back corona in this electric field, the index of the regular corona is 29.0 (The smaller the regular corona index is, the lower the resistivity is and the more easier to collect the dust).

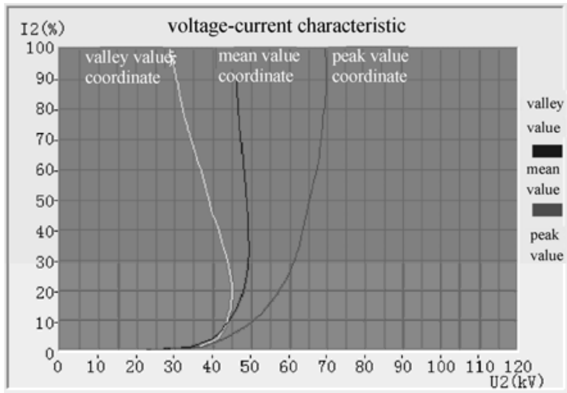


Fig. 1 Back corona of middle degree, Back corona index is 46.4

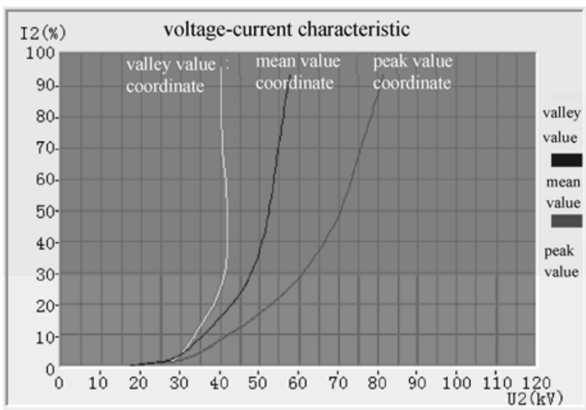


Fig. 2 No back corona, Regular corona index is 29.0s

The analysis results of the operation conditions characteristics in some power plants are shown in Table 1.

Table 1 The analysis results of the operation conditions characteristics in some power plants

Power plant units	Back-corona index Av.	Regular-corona index Av.
Plant A Boiler 1	61.0	
Plant B Boiler 5	60.9	
Plant B Boiler 7	49.3	
Plant C Boiler 1	40.2	
Plant D Boiler 3&4	39.7	
Plant E Boiler 1&2	35.6	
Plant F Boiler 1	34.7	
Plant G Boiler 2	34.5	
Plant H Boiler 5&6	32.7	
Plant D Boiler 1&2	29.2	
Plant I Boiler 2	27.8	
Plant J Boiler 1	No-back-corona	73.0
Plant K Boiler 3	No-back-corona	58.2
Plant L Boiler 3	No-back-corona	41.1
Plant M Boiler 2	No-back-corona	38.0
Plant N Boiler 1	No-back-corona	34.7
Plant O Boiler 2	No-back-corona	27.9
Plant P Boiler 3	No-back-corona	23.2

We have developed a new ESP energy saving software according to the analyses of the on-site working conditions. It can change the feedback control signals from only opacity to many parameters of boiler load, opacity, the gas temperature, flue gas volume and blowing signal etc.. At present, the new software is a closed-loop control system with a main factor and many involved feedback factors, it has three control modes with the feedback of main factors: the boiler load main factor, the opacity main factor and the gas temperature main factor. The control mode with the boiler load as main factor is the best control mode, because the on-site opacity meters often have a high failure rate. With this software package, the IPC system can choose the best running mode of the high-voltage power supply and duty ratio of intermit power supply automatically according to the analysis of the working conditions, which can make the ESP to work in an ideal state of the minimum power consumption and the highest efficiency. The IPC system also can achieve a closed-loop control by amending and adjusting automatically according to the changes of the gas opacity, unit load and some other important parameters, which can achieve the optimum effect and the maximal energy saving.

At the same time, with the compound power down rapping, the IPC system adopts the power-off rapping control strategy of high-voltage control associating with low-voltage rapping. In this way, it can improve the effect of the ESP and the collection efficiency. Correspondingly, the ESP can work stability in a good state with an evidently energy saving effect for a long time.

4 ON-SITE APPLICATIONS

There are two 300 MW units in a power plant, boiler 5 and boiler 6. The two units have the same ESP configurations, and their peacetime running and boiler loads are almost alike. The boiler 6 adopted the new type energy saving control system in its reform, such things were done, as follows: the boiler load signal was connected to the ESP IPC system; the control function of Longking compound power rapping was added; the software of the IPC system and the high and low voltage control were upgraded.

Since being connected to the boiler load signal , the IPC energy saving control system with some main adjusting parameters such as “energy saving intensity” and “load coefficient” can work in the control mode with the boiler load as main factor. The setting of correlative parameters can be seen in Fig. 3.

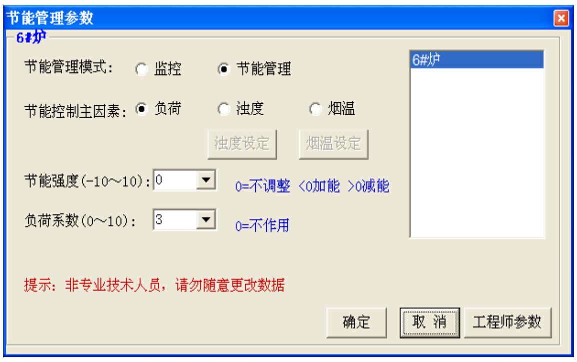


Fig. 3 The sketch for energy saving control parameter settings

After being reformed, the IPC system can generate the current optimum running mode depending on the electric field’s running working conditions and adjust each electric field to work in the best mode according to the load situation automatically. If the load is increased, less energy will be saved, correspondingly, if the load is reduced, more energy will be saved. The system is able to work steadily in the mode of energy saving and emission reduction for a long time by being adjusted the main parameters which are mentioned above. The ESP can work in a good state with an evidently energy saving effect after a period time of debugging. Though the fundamental conditions between the boiler 5 and 6 are similar, the boiler 6 has an evidently energy saving effect. We can see that by comparing the Figs. 4 and 5. The opacity maintains stability which can be seen from the change trend of opacity and the collection efficiency keeps a higher level in the process of the energy saving running. In the Figs. 4 and 5, the red curves stand for the running power consumption of ESP’s high-voltage power supply, while the blue curves stand for the gas opacity value at the outlet.

The statistic of a period of file data from the IPC system data base also suggests that the energy saving effect of the boiler 6 is evident. Take the statistic data in Fig. 6 for an example, the average power of boiler 5 is 599.09 kW while the average power of boiler 6 is 131.79 kW. We can see that the boiler 6 saved energy as much as 78% comparing the boiler 5.

The management departments of the power plant also compared one week's energy which was consumed by the boiler 6. The statistic result suggests that about 80,000 kilowatt-hour electricity has been saved. The energy saving efficiency is very considerable.

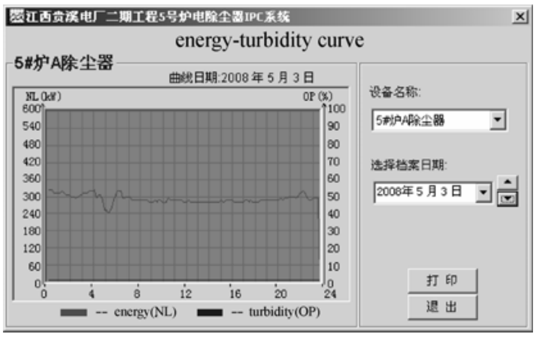


Fig. 4: The running file data curve in the A ESP of boiler 5

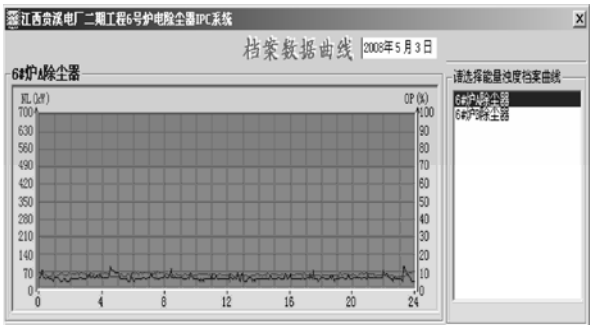
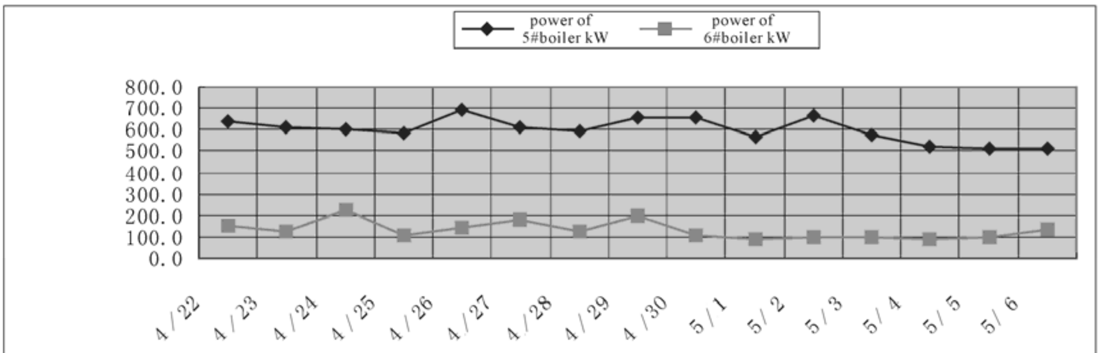


Fig. 5: The running file data curve in the A ESP of boiler 6



	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30	5/1	5/2	5/3	5/4	5/5	5/6
power of 5#boiler	640. 5	610. 1	605. 0	580. 9	690. 8	609. 6	589. 3	656. 5	652. 1	562. 8	661. 0	579. 4	524. 3	512. 8	511. 3
power of 6#boiler	157. 3	124. 5	220. 7	108. 1	140	181. 3	127. 4	195	107. 2	93. 3	102. 9	96	85. 7	100. 6	136. 9

Fig. 6 The average power consumption change trends of the ESP high-voltage power supply of the boilers 5 and 6

5 CONCLUSIONS

The successful application of the new type energy saving control system proved two points. The one is that the ESP can do many things in the field of energy saving and consumption reduction. The other one is that the ESP can save energy while guaranteeing the collection efficiency only by adopting a correct method. Take the 300 WM unit which is mentioned above for an example, it can save energy as much as 78%. 3.2 million kilowatt-hour electricity will be saved if the ESP works 280 hours (40 weeks) one year, and 960000 Yuan RMB will be saved if the price of one kilowatt-hour electricity is 0.3 Yuan RMB. So the economic benefit is pretty considerable. The technology of the power-off rapping and the optimal control mode which both were adopted in the reform can't affect the collection efficiency. Adversely, it can enhance the collection efficiency and reduce the dust emission. The users are very satisfied with the new type energy saving control system. So it is a very worthy thing to extend this system's use range. We need to further optimize and improve the feedback control strategy in the future according to the ESP's on-site conditions. Then the new type energy saving control system will be more perfect and more intelligent, and it will also save more energy while guaranteeing or enhancing the collection efficiency

6 REFERENCE

1. Manfred Schmoch. Methods to Reduce the Energy Consumption of an ESP.