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Study on Performance Optimization of Wet Desulfurization of an Ultra-low Emission Coal-fired Power Unit

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Abstract. The operation mode of slurry recirculation pump and the limestone slurry feed were optimized in order to reduce the power consumption and material consumption of the wet flue gas desulfurization facility in a 330MW ultra low emission coal-fired power unit. The results show that the electricity consumption of WFGD has decreased by optimizing the operation mode of the slurry recirculating pumps. The operating current of the slurry recirculation pumps decreased by 33.25A on average and the electricity charge could be saved 441,000 yuan per year. A feed-forward PID control strategy of limestone slurry feed has been successfully used in the WFGD. A desired tracking performance is achieved and the limestone slurry supply was reduced by 0.0187 ton/ (ten thousand of kWh).

1. Introduction

Coal-fired power plants are one of the main sources of air pollutants in China. In 2014, with much attention paid to the pollutant emission from coal-fired power plants, Chinese government has put forward the ultra-low emission (ULE) for coal-fired power units. The emissions of dust, sulfur dioxide (SO₂) and NO_x are below 10 milligrams per cubic meter, 35 milligrams per cubic meter and 50 milligrams per cubic meter, respectively [1].

Limestone-gypsum wet flue gas desulfurization technology (WFGD) is commonly used in coal-fired units to control SO₂ emission. The implementation of the ultra-low emission standard increases the difficulty of adjusting operation parameters of wet flue gas desulfurization and also increases the operating energy consumption and material consumption of wet flue gas desulfurization [2]. Liquid-gas ratio is an important operating parameter of the WFGD technology, which is determined by the quantity of slurry recirculation pump operating. The electricity consumption of slurry recirculation pump accounts for over sixty percent of the power consumption of the WFGD facility and so optimizing the operation model of slurry recirculation pump is an effective means to minimize the power consumption of the WFGD system [3,4].

The pH of the slurry is another important process parameter in WFGD operating, which affects many performance indexes such as desulfurization efficiency and sorbent conversion, and then it must be controlled in an optimum range (5.0~5.8). The limestone slurry feed flow is controlled according to the pH of the slurry in WFGD tower. When the slurry pH is lower, the limestone slurry feed rate is increasing, and when the slurry pH is higher, the limestone slurry feed rate is lower. The limestone slurry feed is manually controlled by operator, but the manual feed has a large time lag so SO₂



emission concentration fluctuates greatly, even showing negative values, which do not meet the requirements of environmental protection. The manual feed is easy to cause the waste or shortage of limestone slurry [5,6].

This paper has optimized the operation mode of the slurry recirculation pumps according to unit load and SO₂ inlet concentration in order to reduce the power consumption of the WFGD facility in a 330MW ultra-low emission coal-fired power unit. The automatic control strategy of limestone slurry feed has been optimized to improve the automatic control effect and reduce the limestone consumption.

2. Experiment

2.1. Unit overview

This paper takes a 330MW subcritical coal-fired unit as the research object, which is equipped with WFGD facility to control SO₂ emission. The WFGD absorber consists of five slurry recirculation pumps for the five spray levels. The spray levels are named the 1st, 2nd, 3rd, 4th and 5th spray level from the bottom to up respectively, and the corresponding recirculation pumps are named A, B, C, D and E, and the power are 450kW, 500kW, 560kW, 560kW and 630kW respectively. SO₂ concentration at the inlet of WFGD absorber is 3000mg/m³, SO₂ concentration at the outlet is less than 35mg/m³, and therefore the desulfurization efficiency is no less than 98.85% under the design condition [7].

The automatic control strategy of limestone slurry feed before optimization uses a single loop PID controller. The measured slurry pH is compared with the set slurry pH and then the limestone slurry feed flow is controlled by the PID controller. When the measured slurry pH is lower than the set value, the limestone slurry feed rate is increasing, and when the measured slurry pH is higher than the set value, the limestone slurry feed rate is lowering. There is no feed-forward in the control strategy and the influence of fuel sulfur content change and unit load change on the limestone slurry feed is not considered. When the original automatic control strategy of limestone slurry feed is in operating, due to mismatch between the set slurry pH and the work condition, SO₂ emission concentration fluctuates greatly, and the instantaneous SO₂ concentration often exceeds 35 mg/m³. And so the limestone slurry feed is manually controlled by operator.

2.2. Optimization scheme

2.2.1. Optimization of slurry recirculation pump. The operation mode of the slurry recirculation pumps was optimized according to unit load and SO₂ inlet concentration and the optimization scheme was shown in Table 1. During the test, the limestone slurry feed was kept stable, the slurry pH was stable between 5.0 and 5.4, and the limestone slurry density was between 1210kg/m³ and 1230kg/m³.

Table 1. The optimization scheme of slurry recirculation pumps

Unit Load (MW)	SO ₂ outlet concentration (mg/m ³)	Slurry pH	Operation mode of the slurry recirculation pumps
250	10~25	5.0~5.4	A, B, C
300	10~25	5.0~5.4	A, B, E
310	10~25	5.0~5.4	A, B, C, D
335	10~25	5.0~5.4	A, B, C, E

2.2.2. Optimization of automatic control strategy of limestone slurry feed. The SO₂ concentration at the chimney inlet, the differential of SO₂ concentration at the chimney inlet, and the differential of boiler load are set as feed-forward into the original single loop PID controller.

3. Results and discussion

3.1. Optimization of slurry recirculation pump

The emission concentration of SO₂ under different work conditions has met ULE standards after the optimization of slurry recirculation pump as shown in Table 2 and Table 3.

Table 2. The operation of slurry recirculation pump before optimization

Unit load (MW)	SO ₂ inlet concentration (mg/m ³)	SO ₂ outlet concentration (mg/m ³)	Current of slurry recirculation pump (A)					Slurry pH
			A	B	C	D	E	
250	1691	20	59	61	53	0	0	5.6
300	1998	14	59	61	53	42	0	5.0
310	1875	9	59	61	53	42	64	5.1
335	2541	17	59	63	54	42	64	5.4

Table 3. The operation of slurry recirculation pump after optimization

Unit load (MW)	SO ₂ inlet concentration (mg/m ³)	SO ₂ outlet concentration (mg/m ³)	Current of slurry recirculation pump (A)					Slurry pH
			A	B	C	D	E	
250	1676	15	59	61	53	0	0	5.4
300	2173	19	59	61	0	0	64	5.3
310	1889	21	59	61	53	42	0	5.3
335	2644	18	59	63	54	0	64	5.5

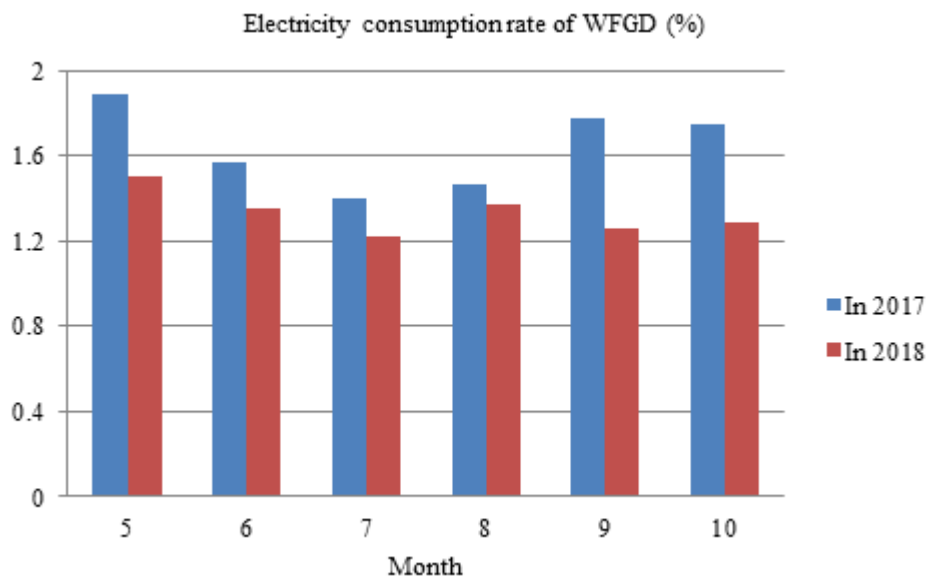


Figure 1. Electricity consumption rate of WFGD

The electricity consumption of WFGD has decreased significantly by optimizing the operation mode of the slurry recirculating pumps under different work conditions. The electricity consumption rate of WFGD has been reduced by 0.31 percentage points after optimization. The operating current of the slurry recirculation pumps decreased by 33.25A on average, and the electricity charge could be saved 441,000 yuan per year when the electricity charge was calculated as 0.30 yuan/(kWh) and the unit utilization hours were calculated as 5000h per year.

3.2. Optimization of automatic control strategy of limestone slurry feed

The proposed feed-forward PID control strategy has been successfully used in the WFGD since February 2018. With the proposed feed-forward control, the control system response is improved because the limestone slurry flow controller rapidly compensates for fluctuations in the gas desulfur

content demand caused by disturbances such as fuel sulfur content or boiler load, without waiting for the eventual pH change in reaction tank. A desired tracking performance is achieved by the proposed feed-forward PID control scheme. SO₂ emission concentration shows fast response and meets ULE standards stably. The slurry pH is stable and does not fluctuate strongly.

The limestone slurry feed changes are shown in table 4 after the proposed feed-forward PID control strategy successfully used. Under similar working conditions, the limestone slurry feed quantity before and after the optimization is compared. The slurry supply of limestone was 0.5382 ton/ (ten thousand of kWh) before optimization, and the slurry supply of limestone was 0.5195 ton/ (ten thousand of kWh) after optimization. The limestone slurry supply was reduced by 0.0187 ton/ (ten thousand of kWh). When the limestone is calculated according to 220 yuan/ton, it will be reduced by 1.09 yuan/ (ten thousand of kWh). When the unit utilization hours are calculated as 5000h per year, the limestone cost can be saved by 182,000 yuan per year.

Table 4. Changes of limestone slurry feed before and after optimization

Time	SO ₂ inlet concentration (mg/m ³)	SO ₂ outlet concentration (mg/m ³)	Electrical generating capacity (ten thousand of kWh)	Limestone slurry amount (ton)	Unit consumption (ton/(ten thousand of kWh))
October 2017	2132.5	13.4	16455.42	8856.69	0.5382
June 2018	2189.6	13.7	10710.90	5563.81	0.5195

4. Conclusion

The electricity consumption of WFGD has decreased by optimizing the operation mode of the slurry recirculating pumps. The electricity consumption rate of WFGD has been reduced by 0.31 percentage points after optimization. The operating current of the slurry recirculation pumps decreased by 33.25A on average, and the electricity charge could be saved 441,000 yuan per year when the electricity charge was calculated as 0.30 yuan /(kWh) and the unit utilization hours were calculated as 5000h per year.

The proposed feed-forward PID control strategy of limestone slurry feed has been successfully used in the WFGD. A desired tracking performance is achieved by the proposed feed-forward PID control scheme. The limestone slurry supply was reduced by 0.0187 ton/ (ten thousand of kWh).

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