Performance test of optimal denitration efficiency of a 350MW unit under the background of new power system

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Abstract. With the establishment of the goal of "carbon peaking and carbon neutralization", a new power system based on new energy is proposed. With the rapid development of ultra-high voltage external power and new energy in Shandong power grid, the difficulty of system peak regulation is increasing. At present, the peak regulation is mainly based on direct regulating thermal power units. The capacity of pumped storage power stations is limited and there are no gas-fired generating units, which also leads to serious shortage of other flexible regulation resources that Shandong power grid can call. In 2022, Shandong Province plans to implement the renewable energy multiplication plan, and it is expected that the installed capacity of new energy will account for 38%. With the large-scale access of new energy, the "double high" characteristics of the power system are highlighted, and the technical characteristics and stability mechanism of the power grid will undergo profound changes. In the new power system with new energy as the main body, the role of thermal power generation has gradually changed from the electric power source to the regulating power source. Under the variable load conditions, find the optimal efficiency conditions and provide necessary data for the optimal denitration efficiency operation.

key word: Deep peak shaving; Optimal denitrification efficiency.

1. Introduction

Now, after a 350MW heating unit is completed and put into operation, it can meet the environmental protection parameter of denitration ultra-low emission 50mg/m3 formulated by the state[1].There are problems such as high ammonia escape rate, uneven NOx distribution at the outlet and low denitration efficiency of SCR device.The chemical reaction formula of denitration process is as follows:

$$4NO+4NH_3+O_2 \rightarrow 4N_2+6H_2O$$

$$2NO_2+4NH_3+O_2 \rightarrow 3N_2+6H_2O$$

The selective catalytic reduction method is selected for denitration process, that is, in the SCR reactor of the tail flue, the flue gas reacts with the injected NH3 to generate nitrogen and water. The selected reductant NH3 is generated by hydrolysis of liquid ammonia and supplied to the denitration unit area[2]. In the mixer, it is mixed with the air provided by the dilution fan and diluted to below 5% volume safety concentration.

2. Establishment of model of out of stock system and field out of stock optimization test

The main purpose of establishing the denitration model is to test whether the flow field design of the denitration device is reasonable. By optimizing some key positions and parts in the denitration flow field, such as the inlet section of the ammonia injection grid, the inlet section of the catalyst layer, and the baffle, etc., a uniform flue gas distribution is established in the SCR reactor before the ammonia injection mixing. At the same time, the performance of the static mixer is tested and optimized.

The study of denitration flow model will include the flue from the outlet of boiler economizer to the inlet of air preheater, including: ammonia injection and mixing system at the inlet flue of reactor, ammonia injection grid system and SCR reactor with rectifier. In the denitration device, the flow field that has not been optimized by numerical simulation calculation has poor uniformity of ammonia nitrogen mixing at the inlet, low denitration efficiency, and ultimately leads to high ammonia escape[3].

Therefore, for the denitration device of Baoding northwest suburb thermal power plant, verify whether it

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meets the uniform distribution from the flow field design to ensure uniform flow field distribution, uniform velocity distribution and uniform ammonia nitrogen mixing.

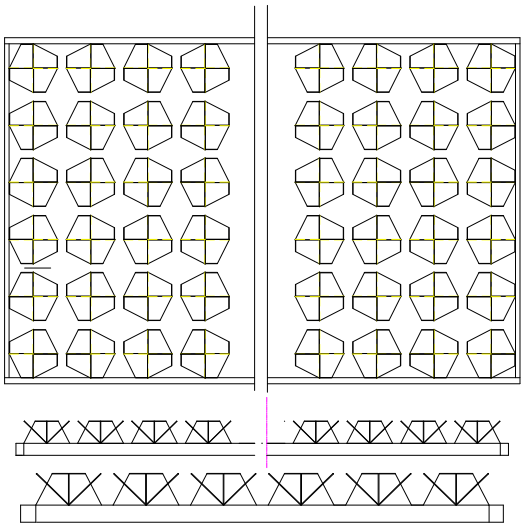

Figure 1. Schematic diagram of AIG blade in the model

2.1 Porous media model

In porous media, momentum, energy and mass transfer phenomena exist widely, especially the study of the fluid movement process in porous media has far-reaching practical value. Porous media model is also widely used in power plants, and the simulation of catalyst layer in this model can also be realized through porous media model. The flow of fluid in porous media channels is various and difficult to describe by simple methods[4]. It is also difficult to describe the resistance and pressure drop. Therefore, appropriate restrictions on the porous media model can play an effective role in modeling, so as to better understand the momentum mechanism of the fluid passing through the partially or completely filled porous media channel . The porous media model established this time has the following limitations:

(1) Most of the research results of numerical calculation are tests carried out under unsteady conditions. In this case, there will be many uncontrollable situations. However, at present, there are very few numerical studies on normal fluid flow, so it is difficult to have accurate numerical reference. In fact, the velocity of the fluid passing through the medium in this model does not change, which means that the transition time of the fluid passing through the medium is not accurately reflected.

(2) In the porous media model, when the fluid is turbulent, fluent will solve the standard conservation equation of turbulent flow by default. Based on this, the solid medium has no influence on the generation and dissipation speed of turbulence[5].

The momentum equation of porous media can be expressed by the following formula, and the additional momentum source term is composed of the following two parts:

$$S_i = \sum_{j=1}^{3} D_{ij}\mu v_j + \sum_{j=1}^{3} C_{ij}\frac{1}{2}\rho|v_j|\cdot v_j \qquad (1)$$

Where is the momentum source term of the direction and D and C are the prescribed matrices.

For simple homogeneous porous media:

$$S_i = \frac{\mu}{\alpha}v_i + C_2\frac{1}{2}\rho|v_j|v_j \qquad (2)$$

Wherein: αIs the permeability factor and C2 is the internal resistance factor.

The catalyst used in the test unit is a plate type, which can be regarded as an isotropic porous medium composed of parallel channels[6]. Its internal resistance coefficient in the flue gas flow direction can be obtained from the test or actual measurement.According to the design requirements, the resistance of $\Delta p_y = 150Pa$ ($\Delta p_y \le 200Pa$) is set in the flue gas flow direction in this simulation to obtain the internal resistance coefficient of the catalyst during calculation:

$$K_y = \frac{1}{2}\rho v_y{}^2 / \Delta p_y \qquad (3)$$

2.2 Field out of stock optimization test

Due to the limitation of load dispatching, it is determined through negotiation by many parties that the continuous operation time at full load from 9:00 to 19:00 shall be the test time, and the test shall not be less than 3 days. The coal quality shall be confirmed by both parties. During the performance assessment test of the unit denitration system, the average load of the unit is 350MW, which is required to meet the requirements of the assessment test and achieve stable and continuous operation. See table 2 for the main operating parameters of the unit during the test. During the test, the 100% load period is from 9:00 to 19:00 every day for 10 consecutive hours. During the test, the inlet NOx concentration range is 200-330mg/Nm^3 (6% O_2) (the NOx concentration during the test is calculated as NO_2), which basically meets the test conditions. During the test, the coal mill shall not be switched and the combustion adjustment shall not be conducted.

The instruments and materials required during the test are shown in the following table:

Table 1 Required instruments and materials

Serial number:	Instrument name:	Model and number	unit	quantity
1	flue gas analyzer	MGA5+	set	2
2	Electronic micropressometer	SWEMA 3000	platform	1
3	GASMET Fourier infrared analyzer (including SO_3, HF, HCl, NO_2, etc.)	FT-IR DX4000	platform	1
4	Total composition flue gas analyzer	U23	platform	2
5	Oxygen analyzer	Kane KM900	platform	2
6	Precision electronic balance	CPA225D	platform	2
7	Digital thermometer	51П	set	2
8	Dust tester	3012H	set	4
9	Thermocouple	Fluke F52	set	3

Table 2 Main operating parameters of the unit during the test

project	7/27	7/28	7/29
Actual power	344.44	342.50	349.41
Main steam pressure	24.12	23.96	24.30
Steam pressure of reheat hot section	3.91	3.94	3.92
Main steam flow	1065.47	1044.29	1115.56
Outlet steam temperature of high temperature superheater	562.66	567.12	567.58
Outlet temperature of high temperature reheater	562.98	566.64	567.53
Fuel quantity after calibration	150.05	148.05	154.57
Outlet flue gas temperature of air preheater a	149.11	148.31	149.97
Outlet flue gas temperature of air preheater B	149.82	149.54	146.01
Oxygen content of flue gas at outlet of air preheater a	3.05	2.68	2.83
Oxygen content of flue gas at outlet of air preheater B	3.32	3.15	3.11

3. Conclusion

The flue gas parameters were tested at the inlet of SCR reactor. The flue gas analyzer at the outlet of the reactor is used to measure the content of NOx and O_2 at the inlet and outlet of the reactor. At the same time, the NOx and O_2 data of CEMS dial are recorded, and the display correction coefficient of NOx and O_2 dial is obtained through comparison. Denitration efficiency is calculated as follows:

$$\eta = (C_{NOx\ in} - C_{NOx\ out}) / C_{NOx\ in} * 100\% \quad (3\text{-}1)$$

The denitration system meets the reading of CEMS at the inlet and outlet of denitration as required by the assessment, and the CEMS reading is corrected according to the measured flue gas parameters of side a and the calibration coefficient of CEMS reading at the inlet and outlet of side B, and the test results are obtained. The final result is that the average denitrification efficiency of side a and side B is 92.85% and 92.33% respectively at 100% load, and the outlet NOx (calculated as NO_2) concentration is 16.03mg/nm^3 (6% O_2) and 18.52mg/nm^3 (6% O_2) respectively.Through comparison under different load conditions, it can be concluded that the denitrification performance is the best when the unit burns design coal and operates under 100% load, the NOx concentration distribution at the outlet section is relatively uniform, and the ammonia escape is also low.

Acknowledgements

This work is supported by the science and technology project of Electric Power Research Institute of State Grid Shandong electric power company(ZY-2022-15), which studies Research on peak capacity improvement of thermal power unit based on electric heating coordination optimization under guaranteed supply demand.

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