Study on Optimization Experiment of SCR Denitrification Technologies in a Coal-fired Power Plant

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Abstract. Optimization experiment of SCR denitrification technologies on a 300MW unit was conducted. Adjustment of ammonia injection quantity of corresponding AIG was conducted after measuring the SCR export NOx concentration field in 250MW load, the distribution uniformity of NOx volume fraction at the outlet of both reactor A and B was improved significantly, where the relative standard deviation of NOx reduced respectively from 29.83% to 13.01% and 24.54% to 9.26%, simultaneously, the amount of ammonia escape of A, B reactor decrease respectively by 24.76%, 19.45%. The results of optimization experiment show that, optimal adjustment can improve the NOx concentration distribution, reduce the amount of ammonia escape in a certain extent, and judge whether the catalytic activity of the regional catalyzer is in good condition. As to the area where catalyst is ineffective, the effect of optimization experiment is limited, the catalyzer should be the timely replacement, so as to better protect downstream equipment.

1. Introduction
Since the Chinese standard named Emission standard of air pollutants for thermal power plants:GB 13223-2011[1] was published, the domestic coal-fired power plant has carried on a large-scale transformation of desulfurization and denitration in China, the Selective Catalytic Reduction Process(SCR) technology has become the primary choice of denitration, because of its high denitration efficiency and mature technology[2-4].The SCR system of domestic coal-fired power plants was put into operation before 2014,with the running time, more and more erosion, jams, poisoning evens occurred in reactor catalyst layer ,which reduced denitration efficiency of SCR system and increased ammonia escape, threaten the safety and operation of downstream equipment.

Optimization experiment of SCR denitrification technologies on a 300MW unit was conducted in this paper. After the SCR system of testing coal-fired power plant put into operation many years, the resistance of air-preheater increases gradually, and more fly ash adhere to the blades of induced draft fans recently. It may be caused by the poor matching of ammonia injection, the increase of ammonia escape, and the ammonia hydrogen sulfate that adhere to the downstream equipment. The optimization experiment of SCR system was conducted in 250MW load which is the long period running condition of testing coal-fired power plant.
2. Equipment and Test Method

2.1. Equipment Introduction
This thesis selects the SCR system of a 300MW coal-fired power plant as the testing objective, the system consists of A and B reactor that adopt the liquid ammonia as the denitration reducing agent. The reactors were installed between the economizer and air preheater, including three cellular catalyst layer, one layer is reserved.

2.2. Test Method
The method of field test as follows: first of all, the initial test and optimization experiment of SCR system was conducted in 250MW load which is the long period running condition of testing coal-fired power plant. In this paper, the grid method was used to measure the concentration distribution of NOx and ammonia. The amount of ammonia escape was measured by chemical absorption method, and flue gas composition was tested by flue gas analyzer named NOVA 2000. The measurement points are numbered along the reactor width from A side to side B, followed by A1 ~ A9, B1 ~ B9, and every measuring point includes three joints named the remote, the middle, the proximal according to the direction of the depth of the flue. Proximate analysis of coal during the experiment is shown in table 1.

Table 1. Proximate analysis of coal

| Item | Mt | Mad | Aad | Vdaf | Fcad | St,ad | Qnet,ar |
|------|----|-----|-----|------|------|-------|---------|
| Unit | %  | %   | %   | %    | %    | %     | MJ/kg   |
| Value| 7.63 | 0.74 | 20.87 | 14.45 | 67.03 | 0.74 | 25.48   |

3. Test results and Analysis

3.1. Results before optimization
Efficient SCR denitration system mainly depends on catalyst properties, parameter distribution of flue gas at inlet of the dinitrification system and design of SCR reactor\([5]\). Velocity of flue gas at inlet of the first catalyst bed determines the gas residence time in the catalyst layer, high speed means short reaction time, which lead to a higher NOx concentration of the corresponding outlet area\([6]\). In addition, erosion, abrasion, or congestion, which shorten the service life of catalyst, will occurred under a bigger or lower velocity. Fig.1 shows the velocity distribution of flue gas at inlet of SCR reactors in 250MW load. As Fig.1 illustrates, the inlet velocity distribution of both A and B reactors is very uneven, the velocity relative standard deviation were 23.5% and 25.6% respectively, which were greater than the value (15%) that the design, operation optimization of reactor required. The velocity distribution is bound to be harmful to the unit catalyst layer. Therefore, the reactor rectifier device should be improved or optimized, in order to reduced impacts on NOx distribution on exports and the amount of ammonia escape.

Most of SCR denitration system adjust spray amount of ammonia based on the feedback of NOx emission values at the present stage \([5]\). However, the feedback of NOx emission values is taken from the individual representative measuring points, rather than the total cross section measurement, once the distribution of NOx at outlet of reactor appeare seriously uneven, the ammonia injection strategy needs to be optimized, to avoid increasing ammonia escape. Fig.2 shows the distribution uniformity of NOx volume fraction at the outlet of reactor A and B before the adjustment, it can be concluded that the relative standard deviation of NOx on both sides of the reactor were over 15%. The distribution characteristics of NOx on the A side shows that the left measuring points value is higher than the right, while it is the value of middle measuring points higher than both sides on the B side.
It can be found by comparing the laws illustrated in fig.1 and 2 that they are obviously different. Then we can see that the difference of residence time caused by flue gas velocity is not mainly reasons that lead to the uneven distribution of the NOx. According to Arrhenius’law and elementary reaction of SCR, it can be conclude that the main reasons for the large deviations of NOx distribution at the outlet of SCR reactor is that the amount of injecting ammonia of AIG and the activity of catalyst in the reactor[6].

3.2. Result and Analysis after Optimization
Optimization and adjustment of ammonia injection test is that according to the measurement results of NOx distribution at outlet of SCR system, adjust the valve opening of AIG in the upstream to change the amount of ammonia spray in each mesh region, until the relative standard deviation of NOx at outlet of reactor was less than 20%. The principle of the first adjustment is that for the area where the NOx is higher, the amount of ammonia injected into the upstream grid should be increased, for the area where the NOx is smaller, the amount of ammonia injected into the upstream grid should be reduced. After the first optimized adjustment, the NOx concentration distribution on the A and B sides of the reactor is shown in fig.3. As can be seen, the concentration of NOx at the outlet of both reactor A and B was greatly improved, and the relative standard deviations are reduced from 29.8% and 24.54% to 13.01% and 9.26% respectively.
The distribution uniformity of NOx (mg/Nm$^3$)
Number of the measurement points of reactor A
the remote joint
the middle joint
the proximal joint

The distribution uniformity of NOx (mg/Nm$^3$)
Number of the measurement points of reactor B
the remote joint
the middle joint
the proximal joint

Fig.3 the distribution uniformity of NOx at the outlet of reactor after the first adjustment

Research$^{[7]}$ have suggested that the sulfur content in coal will affect the formation of SO$_3$ in flue gas, which affect the production of hydrogen sulfate ammonia. As can be seen from table 3, the long-term fuel of this unit is of a kind of low sulfur coal, and the ammonia escape amount should be under 6ppm at least$^{[7]}$. Fig.4 shows the comparison of ammonia escaping from each measuring point before and after adjustment. As can be seen, the average ammonia escape amount at outlet of reactor B has been reduced to below 6ppm after adjustment. But for the reactor A, although the distribution of NOx was greatly improved, the ammonia escape rate decreased slightly which is still higher than 6ppm. According to figure 2 and figure 3, it can be concluded that: it is due to reduction of catalyst activity, especially for A1 to A3 measuring point, although the amount of ammonia injected by upstream AIG increased, NOx decreased slightly, and the ammonia escape was significantly increased, indicating that the regional catalyst may have been disabled$^{[8,9]}$.

Fig.4 Comparison of ammonia escaping from each measuring point before and after adjustment

In order to minimize the ammonia escaping from reactor A, optimization and adjustment was proceed. The principle of second ammonia injection optimization adjustment is: in the premise of ensuring the NOx emission at outlet does not exceed relevant environmental standards, to reduce the amount of ammonia injection where is suspected failure district of the catalyst, increasing the ammonia injection quantity where the change of NOx concentration responding to the amount of ammonia spray better. As shown in Figure 5, the results of the second optimized adjustment show that although the relative standard deviation of the export NOx distribution is increased from 13.01% to 19.83%, the ammonia escape rate is reduced by 20% compared with the first adjustment. Therefore, this method is more feasible in terms of protecting the downstream equipment.
4. Conclusions and Suggestions

1). The guiding device of flue gas into the catalytic reactor should be optimized, ensuring the relative standard deviation of gas velocity before first catalyst layer within 15%, so as to avoid the erosion, wear, fouling, and clogging of the catalyst layer, prolonging the service life of the catalyst.

2). Under the premise of better catalytic activity, the ammonia adjustment optimization test can greatly improve the distribution uniformity of NOx at the outlet of SCR system. Optimization test of SCR can determine whether catalytic activity is in a good condition: if the amount of ammonia injected by upstream AIG increased, NOx decreased slightly, and the ammonia escape was significantly increased, indicating that the regional catalyst may have been disabled, the catalyst should be replaced or regenerated timely.

3). When the catalyst activity becomes worse, the principle of ammonia injection optimization adjustment should be: in the premise of ensuring the NOx emission at outlet does not exceed relevant environmental standards, not excessively pursue NOx uniformity of SCR system, in order to reduce the amount of ammonia escaping, then avoid the harm of hydrogen sulfate ammonia to the downstream equipment.

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