Causes and Countermeasures for Decrease in Denitration Efficiency and Excessive Ammonia Escape in SCR System of Coal-fired Power Plants

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Abstract. The good operation of the SCR flue gas denitration system in coal-fired power plants is of great significance to the environment. This paper introduces the denitrification efficiency drop and the ammonia escape exceeding standard in the operation process of a coal-fired power plant denitritification device. According to the actual situation of the plant equipment and the field investigation results, the problem is analyzed in depth, and the test measures for the optimization of ammonia injection are proposed. Through experiments, reducing the NOx concentration distribution of the outlet is to improve the denitration efficiency of the SCR system, at the same time reduce the ammonia escape rate of the denitration outlet, and ensure the safety, continuity and economical stable operation of the unit equipment.

1. Introduction

At present, selective catalytic reduction (SCR) denitration system has become an important equipment for large coal-fired units to achieve ultra-low emission, but some problems are also exposed during use, such as uneven flow field of flue gas inlet and unreasonable distribution of AIG ammonia, the air preheater pressure difference exceeding the design value, catalyst wear and poisoning [1-3], etc, which has a significant impact on the safety and economic operation of the unit. The core of SCR denitration technology is catalyst and ammonia injection mixing system. The advantages and disadvantages of ammonia injection mixing system design and the rationality of ammonia injection in actual operation have obvious influence on the operation effect of denitrification device. Due to the rush of the new structural modification of the denitration system and the lack of experience, the optimization of the ammonia injection optimization test in the existing SCR flue gas denitration system [4-6] is the main measures to improve Denitration efficiency and to reduce ammonia escape by accurately monitoring the NOx distribution at the denitrification outlet of the ultra-low emission transformation unit at present.

This paper analyzes the causes of the decrease of denitrification efficiency and the problem of ammonia escape exceeding the standard in a coal-fired power plant, and puts forward the countermeasures of ammonia injection optimization. After the corresponding measures were taken by the power plant, the uniformity of NOx distribution in the outlet section was significantly improved, the peak of ammonia slip was reduced, and the maximum denitration efficiency of the SCR system was increased by about 6% under the same load condition.
2. Introduction of denitration system and ammonia injection system
The denitration system of Unit 2 (300MW) in a power plant adopts a single furnace double SCR structure, high temperature and high ash type, and is arranged between the economizer and the air preheater, and is arranged symmetrically above the primary fan and the blower frame with the boiler center line. The reducing agent is liquid ammonia. The denitrification ultra-low reform of the power plant is carried out on the basis of the existing denitration device, and the layer catalyst is added to the equipment. After adding 1 layer of catalyst, the design efficiency is 87.5%.

The plant's ammonia and flue gas hybrid injection system (AIG) is designed with linear controlled injection grid technology. A plurality of branch pipes are respectively introduced along the mutually perpendicular directions of each flue, and a plurality of nozzles are arranged on each branch pipe, and the flow rate of each branch pipe can be separately adjusted to match the NOx content in the flue gas. This traditional ammonia spray grid arrangement is convenient and advantageous for boiler control with uneven distribution of flue gas and NOx, but the disadvantage is that the system is complicated, the equipment runs for a long time, and individual nozzles are easily blocked.

3. Denitration efficiency decreases and ammonia escape exceeds the standard during operation
According to the actual operation situation of the plant after the ultra-low transformation and operation, common problems in the operation of SCR denitrification system, such as the decrease of denitration efficiency and the increase of ammonia escape rate, result in exceeding the standard.

3.1. Reasons for the decrease of denitration efficiency
The main reasons for the decline in denitration efficiency from on-site investigations are as follows: the regulating process of the denitrification equipment itself has the following faults: insufficient ammonia supply leads to large opening of the flow control valve; too high NOx set value of 40 mg/m³ at the reactor outlet; uneven distribution of injection due to partial AIG blockage; wrong signal displayed by the analyzer; and too low ammonia/NOx mole ratio set value.

In this regard, the following measures are adopted:
(1) The power plant should adjust the outlet NOx set point to an appropriate value of 34 mg/m3 and increase the ammonia injection flow rate as appropriate.
(2) Re-adjust the AIG pressure reducing valve is to increase the amount of ammonia supplied to the nozzle with too little ammonia. Check if the ammonia flow nozzle is clogged.

3.2. Reasons for excessive ammonia escape
Ammonia escape rate is measured by ammonia concentration detector installed downstream of catalyst. In operation, the alarm is given when the ammonia concentration is greater than 2 ppm; when it is greater than 5 ppm, it is required to stop spraying ammonia. From the actual situation of power plant operation, there is very little ammonia escape rate exceeding 5ppm, but since there is no ammonia analyzer at the denitration inlet, the actual efficiency and the actual state of the catalyst cannot be effectively evaluated. Because the ammonia escape rate does not exceed the standard only when the actual efficiency exceeds the design value, the catalyst state is good.

The main reasons for the excessive ammonia escape rate are as follows:
(1) The ammonia mass concentration measuring device at the mixing nozzle fails, resulting in an excessive concentration of ammonia, resulting in an increase in ammonia slip rate.
(2) The uneven distribution of the ammonia spray grid causes local unevenness of the ammonia concentration.

In addition, the amount of NH3 input exceeds the design amount, and the reaction rate of side reactions such as NH3 oxidation will increase. For example, SO2 is oxidized to form SO3, and under low temperature conditions, SO3 reacts with excess ammonia to form ammonium hydrogen sulfate [7]. Ammonium hydrogen sulfate will adhere to the surface of the heat exchanger element of the cold section of the catalyst or air preheater, resulting in reduced denitration efficiency or blockage of the air preheater, increased flue resistance and reduced heat transfer of the air preheater.
4. Measures of ammonia injection optimization adjustment
Based on the analysis of the above reasons, combined with the design limitations of the existing AIG, the existing AIG was optimized and adjusted by the power plant discussion.

4.1. Test methods and contents

4.1.1. NO$_x$ and O$_2$ distribution at the outlet. On the cross section of the flue of the SCR reactor outlet, the flue gas sample was collected point by point by grid method, and the NO and O$_2$ of each point were analyzed by the multi-function flue gas analyzer Testo 350, and the outlet NO$_x$ concentration distribution was obtained synchronously. Calculate the average concentration of NO$_x$ at the outlet of the SCR reactor (standard, dry basis, 6% O$_2$) and view the actual denitration efficiency of the DCS screen of the SCR system.

4.1.2. NH$_3$ escape concentration. According to the concentration distribution of NO$_x$ and O$_2$ in the outlet section of each reactor, several representative points are selected (the representative points should cover the measurement points of different regions with high, medium and low NOx concentration, and the average NO$_x$ concentration of the representative points is equal to the average NO$_x$ concentration of the section) as NH$_3$ sampling point. The ammonia concentration values at the sampling points of the reactor outlet flue were measured point by point using a portable laser method ammonia escape measuring instrument RB120-NH$_3$.

The optimized adjustment test of the SCR device is carried out under normal conditions of the unit, including preliminary test conditions and formal test conditions. The denitration efficiency and the ammonia slip concentration were simultaneously performed, and the parallel working condition test method was adopted, and the average value was taken as the final result.

4.2. Test standards

| Standard Number | Standard Name |
|-----------------|---------------|
| DL/T 260-2012   | Specification for performance acceptance test of flue gas denitration system for coal-fired power plants |
| GB/T 16157-1996 | Determination of particulate matter in fixed pollution sources and sampling method of gaseous pollutants |
| DL/T 362-2016   | Evaluation technology for environmental protection facilities of thermal power plants |
| GB/T 21509-2008 | Coal-fired flue gas denitration technology equipment |
| GB 13223-2011   | Thermal power plant emission standards for atmospheric pollutants |

4.3. Test results

4.3.1. Preparatory test. After discussion by the power plant, preliminary tests were carried out under actual conventional load conditions of 210 MW to test the NO$_x$ concentration and ammonia slip concentration distribution of the SCR denitration system, and the overall operation status of the denitration system and the distribution of the ammonia flow rate were initially evaluated. Under the test load and the corresponding denitration efficiency, test the flow characteristics of the grid manual valve, grasp the influence of the valve opening change on the ammonia flow rate, and master the influence of the ammonia injection manual valve control flow on the SCR outlet NO$_x$ mass concentration.

Under the preliminary test conditions of 210 MW, the distribution of NO$_x$ concentration at the outlet is shown in the figure below. The results show that the NO$_x$ concentration field distribution at
the outlet of the denitration device was not uniform. The measurement points such as A1, A2, A3 on the A side of the local area and B1, B2, B8 and B9 on the B side showed that the NOX concentration was too high and the ammonia injection amount was insufficient; A side A5, A6, A7, A8, B side B3, B4, B5, B6 and other measuring points showed that the NOX concentration was too low, ammonia escape was high. The average NOX of the A side outlet was 38 mg/m³ (standard, dry basis, 6%O2), the relative standard deviation was 50.68%; the average value of the NO exit of the B side was 30 mg/m³ (standard, dry basis, 6%O2), the relative standard deviation was 29.50%. By looking at the synchronous on-site DCS screen, it was found that the denitration efficiency was 82.79% on the A side and 85.52% on the B side.

![Graph 1](image1.png)
Relative standard deviation of side A: 50.68%
Fig. 1. NOX concentration distribution on the side of SCR denitration outlet A in Preparatory test

![Graph 2](image2.png)
Relative standard deviation of side B: 29.50%
Fig. 2. NOX concentration distribution on the side of SCR denitration outlet B in Preparatory test

At the same time, under the condition of unit load 210 MW, the lowest point of NOX concentration of each reactor was selected as the highest point of NH3 escape as the sampling point, and the ammonia escape was tested. Table 2 shows the test results of ammonia slip concentration on the A and B sides of the denitration system. The results showed that the average ammonia slip concentration of the deaerator A side outlet representative point (A5) was 4.0 ppm, which exceeded the design value of
3 ppm, and the B side outlet representative point (B4) averaged the ammonia escape concentration to be 2.7 ppm.

Table 2. SCR denitration outlet ammonia escape concentration in Preparatory test

| A side representative point (A5) | Ammonia escape concentration (ppm) | B side representative point (B4) | Ammonia escape concentration (ppm) |
|----------------------------------|------------------------------------|-----------------------------------|------------------------------------|
| P1                               | 4.1                                | P1                                | 2.7                                |
| P2                               | 4.1                                | P2                                | 2.8                                |
| P3                               | 3.9                                | P3                                | 2.4                                |
| P4                               | 4.0                                | P4                                | 2.9                                |
| A side average                   | 4.0                                | B side average                    | 2.7                                |

4.3.2. Official test of ammonia injection optimization adjustment. According to the preliminary test data, the manual ammonia injection valve opening degree is adjusted in a targeted manner: firstly, the ammonia injection amount in the region with higher NO\textsubscript{X} is appropriately adjusted, and the ammonia injection amount in the lower region of NO\textsubscript{X} is reduced; and the SCR outlet measurement is gradually adjusted. The NO\textsubscript{X} mass concentration of the holes and the measuring points makes the distribution substantially uniform.

Under the same load of 210 MW, after several optimizations of ammonia injection, the concentration distribution of NO\textsubscript{X} at the outlets of A and B was significantly improved. The average value of NO\textsubscript{X} on the A side was 36 mg/m\textsuperscript{3} (standard, dry basis, 6%O\textsubscript{2}), the relative standard deviation was reduced from 50.68% before adjustment to 10.32%; the average value of NO\textsubscript{X} on the B side was 35 mg/m\textsuperscript{3} (standard, dry basis, 6%O\textsubscript{2}), the relative standard deviation decreased from 29.50% before adjustment to 12.15%. Simultaneous viewing of the on-site DCS screen showed that the denitration efficiency was 90.01% on the A side and 91.13% on the B side, which was about 6% higher than before.

![Fig.3. Distribution of NO\textsubscript{X} concentration at the A side outlet after optimization adjustment](image-url)

Relative standard deviation of side A: 10.32%
Fig. 4. Distribution of NO\textsubscript{X} concentration at the B side outlet after optimization adjustment

The ammonia slip concentration test was carried out simultaneously on the optimized denitrification system. Table 3 shows the test results of ammonia slip concentration on the A and B sides of the denitrification system after adjustment. Under the condition of unit load 210 MW, the average ammonia slip concentration of the A side outlet representative point (A5) was 2.2 ppm, and the average ammonia escape concentration of the B side outlet representative point (B4) was 1.4 ppm. Ammonia escape was reduced to meet the design value of no more than 3 ppm.

Table 3. Ammonia removal concentration at the outlet of the denitrification device after optimization adjustment

| A side representative point (A5) | Ammonia escape concentration (ppm) | B side representative point (B4) | Ammonia escape concentration (ppm) |
|---------------------------------|----------------------------------|---------------------------------|----------------------------------|
| P1                              | 2.4                              | P1                              | 1.3                              |
| P2                              | 2.3                              | P2                              | 1.6                              |
| P3                              | 1.9                              | P3                              | 1.5                              |
| P4                              | 2.0                              | P4                              | 1.1                              |
| A side average                  | 2.2                              | B side average                  | 1.4                              |

5. Results and Suggestions

5.1. Results
This paper discusses the problem of the denitrification efficiency of the SCR flue gas installation of a coal-fired power plant and the excessive escape of ammonia, which affects the safe operation of the boiler system. In this regard, after the ammonia spray optimization adjustment test, the uniformity of the NO\textsubscript{X} distribution of the outlet section was significantly improved, and the peak of the ammonia escape was lowered, so that the maximum denitrification efficiency of the SCR system was improved by about 6% under the same load condition. The experience of this paper is effective and provides reference for the optimization of ammonia injection for the same type of unit.

5.2. Suggestions
During the operation, pay attention to the escape rate of ammonia. Strengthen on-site technical management, form a regular calibration system for ammonia mass concentration measuring device and
ammonia escape monitoring instrument to ensure reliable and easy to use. In an abnormal situation, when the ammonia gas escape rate is high, the denitrification efficiency must be lowered to restore the ammonia gas escape rate to a normal level. The inlet flue gas flow rate is measured and the nozzle valve is adjusted. It is recommended that periodic tests can find hidden defects in the system, such as uneven flow rates caused by damage to the deflector.

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