Research on precise ammonia injection technology in thermal power plant

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Abstract. Under the situation of ultra-low emission in China, SCR denitration system generally has the problem of high ammonia escape from the reactor outlet, and the escape ammonia reacts with SO₃ in flue gas to generate NH₄HSO₄, which will aggravate the blockage of air preheater and affect the denitration efficiency, so the ammonia injection has a great impact on the NOx emission concentration of power plant. In this paper, how to accurately spray ammonia in SCR denitration system is introduced in detail, that is, after the flow field partition optimization of denitration system, the corresponding advanced measurement system, advanced control system and actuator are added combined with the partition.

1. Introduction

1.1. Background

On September 12, 2014, The National Development and Reform Commission, the Ministry of environmental protection and the National Energy Administration in China jointly issued the "coal power energy saving and emission reduction upgrading and transformation action plan (2014-2020), which requires that the mass concentration of NOx emission from coal-fired power plants reach the limit of 50mg/m³." At present, NOx control technology is mainly divided into the following three categories: fuel denitrification technology, low nitrogen combustion technology and flue gas denitrification technology. Flue gas denitrification technology as the most important means of denitrification in thermal power plants, there are mainly two methods: selective catalytic reduction (SCR) and selective non catalytic reduction (SNCR).

The main equations of SCR are as follows:

\[
\begin{align*}
4\text{NO} + 4\text{NH}_3 + \text{O}_2 & \rightarrow 4\text{N}_2 + 6\text{H}_2\text{O} \\
6\text{NO} + 4\text{NH}_3 & \rightarrow 5\text{N}_2 + 6\text{H}_2\text{O} \\
6\text{NO}_2 + 8\text{NH}_3 & \rightarrow 7\text{N}_2 + 12\text{H}_2\text{O} \\
2\text{NO}_2 + 4\text{NH}_3 + \text{O}_2 & \rightarrow 3\text{N}_2 + 6\text{H}_2\text{O}
\end{align*}
\]

The main equations of SNCR are as follows:

When ammonia is used as reducing agent:

\[
4\text{NO} + 4\text{NH}_3 + \text{O}_2 \rightarrow 4\text{N}_2 + 6\text{H}_2\text{O}
\]

When urea is used as reducing agent:

\[
4\text{NO} + 2\text{CO} \left( \text{NH}_2 \right)_2 + \text{O}_2 \rightarrow 2\text{N}_2 + 2\text{H}_2\text{O} + \text{CO}
\]

SCR is widely used in thermal power plants because of its mature technology, high denitration efficiency and stable operation and SNCR is often used as an auxiliary means of denitration.

The SCR denitration system uses ammonia injection into the flue. After ammonia is mixed with
nitrogen oxides in the flue gas, nitrogen and water are generated under the action of catalyst. However, SCR denitration system generally has the problem of high ammonia escape from the reactor outlet. And the escaping ammonia reacts with SO$_3$ in flue gas to form NH$_4$HSO$_4$. The main equations are as follows:

$$\text{NH}_3 + \text{SO}_3 + \text{H}_2\text{O} \rightarrow \text{NH}_4\text{HSO}_4$$

$$2\text{NH}_3 + \text{SO}_3 + \text{H}_2\text{O} \rightarrow (\text{NH}_4)_2\text{SO}_4$$

NH$_4$HSO$_4$ is highly viscous and corrosive. It is not only easy to adhere to the upstream catalyst surface, but also easy to block and corrode the downstream air preheater, affecting the denitration efficiency. Therefore, in SCR denitration system, the control effect of ammonia injection has a great influence on the NOx emission concentration of power plant. However, the main problems of ammonia injection measurement system are as follows: single point sampling measurement, the measured value is not representative; the sampling pipeline of CEMS is long and there is measurement hysteresis and the measurement of ammonia escape rate is difficult and the accuracy of the instrument is limited. The above three reasons make it impossible to accurately measure the ammonia escape rate at the denitration outlet, or even display the accurate ammonia escape concentration. In order to solve the above problems, the researchers put forward the concept of "precise ammonia injection".

1.2. Research status
Due to the large-scale ultra-low emission transformation of coal-fired power plants in China, the research practice of precision ammonia injection technology in China is more than that in other countries.

Ye Funan et al. have developed an online monitoring system for NOx concentration distribution in flue gas, which has been successfully applied in a 700MW unit of a power plant. The system is mainly composed of three parts: flue gas sampling module, intelligent patrol control module and flue gas analysis and detection module. Firstly, several groups of grid sampling probes are arranged in the ammonia injection area of the flue gas sampling module. Secondly, the distribution of NOx concentration in SCR outlet flue is monitored on-line by intelligent patrol control module. Finally, after analyzing the measured data in the flue gas analysis and detection module, it is used for online optimization of SCR operation. Combined with the automatic control of ammonia injection control valve, the ammonia injection system is accurately controlled.

Xiao Yujun et al. compared and analyzed the performance of typical SCR devices after optimization, and combined with numerical simulation to analyze the influence of branch pipe installation mode on the uniformity distribution of NOx concentration at the outlet. The characteristics of ammonia injection branch pipe of test device 2 are consistent with those of device 1 before optimization. The transverse section is divided into strip-shaped equal area control area, and there is a problem that the ammonia injection quantity cannot be adjusted in the longitudinal flue gas flow field. After the optimization of unit 1, the branch pipe of ammonia injection grid is divided into several equal area areas to control the amount of ammonia injection. The optimized device 1 can achieve uniform ammonia injection in the control area, and the standard deviation of flue gas velocity distribution in the ammonia injection area of the inlet flue is significantly better than that of device 2.

2. Introduction of precise ammonia injection
Firstly, the flow field of SCR denitration system should be optimized by partition, that is, the original ammonia injection pipeline should be transformed by partition, and the corresponding advanced measurement system, advanced control system and actuator should be added in combination with the partition.

Because the instrument can not accurately measure the ammonia escape rate, it is difficult to control the amount of ammonia injection. Advanced measurement system can be used to measure NOx value to solve the problem of difficult accurate ammonia injection caused by the limited accuracy of measuring instruments. Meanwhile the advanced control system is used to solve the problem of measuring instrument lag and realize NOx concentration prediction. And then, the control mode of the
valve is changed from manual to automatic through the execution system to improve the mixing degree of ammonia and flue gas, control the amount of ammonia injection reasonably and achieve precise ammonia injection.

2.1. Advanced measurement system
The advanced measurement system includes: NOx zone measurement system, flue gas measurement system, ammonia escape measurement system, which can accurately control the amount of ammonia injection.

2.1.1. NOx zone measurement system
NOx zoning is to divide the grid area reasonably according to the flue conditions, and then use the dilution method to pretreat the flue gas, and use luminescence chemistry method to take samples at the same time.

Firstly, the flue gas is diluted with clean compressed air and then extracted. Compared with the direct extraction method, the advantages of dilution system is more stable, the failure rate is small, and it is easy to maintain; and the sampling tube does not need to be heated to keep warm, which completely eliminates the influence of condensation on the instrument; in the mean while, the smoke content after dilution is significantly reduced, and it is not easy to block.

After sampling, the diluted flue gas was measured by luminescence chemistry method. At present, there are three common methods to measure NOx: Luminescence Chemistry Method, Ultraviolet difference Method, and Non-dispersive Infrared Method. In contrast, luminescent chemistry method has the advantages of the best accuracy and lower detection limit.

The transformation of ammonia injection pipeline in different zones is conducive to the full contact between reducing agent and NOx, further mixing, thus improving the removal efficiency of NOx. It is more conducive to the real-time feedback of NOx concentration measurement, and adjust the ammonia injection amount according to the NOx concentration, which can solve the problems of denitration inlet flow field and NOx concentration deviation.

2.1.2. Flue gas measurement system
At present, the equal cross-section air volume measurement system is mainly used in flue gas measurement. This method can not reflect the flow velocity when the cross-section of air duct is large but the number of measuring points is small. Even if the number of points is increased, the measured flow rate can only be close to the real flow rate, which can not meet the demand of automatic ammonia injection.

Compared with the constant cross-section air volume measurement system, the measurement deviation of the matrix adjustable air volume measurement system is smaller. Matrix multi-point measurement is adopted, that is, the measuring points are arranged according to the actual flow velocity distribution of the fluid, so as to reduce the calculation deviation of NOx concentration, improve the measurement accuracy of flue gas, and carry out accurate ammonia injection. In the process of use, the automatic ash cleaning device can be added in the matrix adjustable air volume measurement system to avoid the blockage of the flue.

2.1.3. Ammonia escape measurement system
At present, the measurement of ammonia escape mainly adopts the following two methods: extraction method and laser in-situ measurement method.

Extraction method is to use high temperature extraction method to measure NH3 concentration and chemical measurement method to measure ammonia escape concentration, which has the advantages of low dust concentration and is not affected by temperature and pressure fluctuations, low measurement limit and high sensitivity. However, because of the absorption of trace ammonia by water, it is difficult to guarantee the accuracy of the extraction method.

Laser in-situ measurement is based on the monochromatic property of laser, and it analyzes the
absorption characteristics of specific gases. However, the dust in the flue gas can emit, diffuse and absorb the near infrared laser. When the dust concentration is too high, the ammonia escape concentration can not be accurately measured.

Therefore, the method of laser in-situ measurement combined with extraction method can be used to measure the ammonia escape concentration, that is, the measurement chamber is installed in the flue and the samples are evenly sampled in the flue section.

This sampling method does not change the temperature, so it can change the composition of the flue gas to the minimum extent and avoid the influence of dust in the flue gas. It has the advantages of low measurement limit, high sensitivity and online real-time measurement.

The original ammonia injection pipeline is reconstructed in zoning transformation, and the corresponding measurement and control system is added, which can timely feed back the NOx concentration under various unit loads, solve the problem of measurement deviation of denitration inlet flow field and NOx concentration, and realize real-time ammonia adjustment and distribution.

2.2. Advanced control system
Advanced control system can be divided into total ammonia injection control system and ammonia injection grid balance control system.

2.2.1. Total ammonia injection control system
Total ammonia injection control system is the main ammonia injection control mode of denitration system in thermal power plant. Through the measurement and calculation of the inlet NOx concentration, ammonia nitrogen molar ratio, flue gas flow and catalyst conversion efficiency, the total amount of ammonia injection can be obtained. The ammonia flow into the ammonia injection grid is set, and the ammonia flow is adjusted by feedback of NOx concentration at the outlet.

However, the precondition of total amount control system regulation is that the NOx concentration distribution in the denitration system is uniform, the ammonia injection grid is uniform, and the catalyst catalytic efficiency remains unchanged. In the actual operation, due to load fluctuations, operating conditions and other changes, the denitration system can not always be stable. Therefore, in the actual operation, the total ammonia injection control system can not use the automatic operation mode, and basically adopts the manual adjustment mode. Due to the lack of continuous on-line monitoring in the manual regulation mode, the operation workers' experience is highly required, and there is a weakness that the comprehensive monitoring can not be carried out, resulting in the problem of difficult control of ammonia injection.

Therefore, it is necessary to predict, feedback and control the overall working condition of SCR denitration system as far as possible; reduce the fluctuation of NOx concentration at the outlet; and ensure the safe and stable operation of the system in the following two ways: One is to introduce the soft sensing technology into the inlet of ammonia injection total control system. The soft sensing technology can predict the change of NOx concentration at the inlet and solve the measurement error caused by the lag of inlet measurement. Second, after obtaining the transfer function of SCR denitration system under different loads through experiments, the control algorithm model is implemented pertinently. The model has the function of automatic learning, which can find the blockage and wear problems of SCR denitration system in time according to the change of measured data, and adjust them in time. It does not need manual maintenance, and can realize the automatic, intelligent and fine control of SCR denitration system.

2.2.2. ammonia injection grid balance control system
After the flue is partitioned, the ammonia injection proportion of each partition can be optimized by using the ammonia injection grid balance control system. There are several injection holes in different size control areas, and the flow can be adjusted independently. The ammonia injection grid equalization control system has the characteristics of automatic equalization control according to the partition measurement data. The system online controls the ammonia injection ratio of each control
area to make the outlet NOx concentration tend to be consistent. The activity of the catalyst can be judged by combining the ammonia flow value of the partition and the NOx measurement value at the outlet, so as to avoid the instantaneous excess of ammonia injection caused by local catalyst deactivation. At the same time, the system has the advantages of simple structure, not easy to accumulate ash, and can effectively improve the utilization rate of denitration catalyst.

2.2.3. Actuator
SCR denitration system actuator mainly refers to the accurate ammonia injection grid zone and automatic control device, mainly for ammonia injection automatic valve setting. By changing the control mode of ammonia injection grid valve from manual to automatic, the division of ammonia injection grid can be effectively combined with automatic control. The opening of the manual valve can only be changed according to whether the boiler is shut down or whether the test is adjusted periodically. When the NOx concentration changes under different working conditions, catalyst wear failure and flow area blockage, the opening of the manual valve cannot be adjusted in time. The automatic door can more easily adjust the opening, reasonably control the amount of ammonia injection, and improve the even mixing degree of ammonia and flue gas.

3. Conclusion
This paper discusses how to accurately spray ammonia in SCR denitration system, that is, after the flow field partition optimization of denitration system, the corresponding advanced measurement system, advanced control system and actuator are added in combination with the zone. With the coal-fired power plant gradually entering the "post era" of ultra-low emission transformation, the excessive ammonia injection occurred in the operation of denitration system, resulting in a series of problems such as air preheater blockage, dust collector scaling, reducing agent consumption increasing are becoming more and more prominent. The precision ammonia injection technology provides a fundamental solution to the problem. However, the increase of equipment investment cost and operation cost is also one of the realistic situations that the large-scale promotion of the scheme will face. The power plant needs to make a comprehensive decision based on economy and environmental protection.

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