Boiler Bypass Flue to Adjust Denitration Inlet Flue Temperature Automatic Control System Design and Analysis

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Abstract. Under low-load boiler operating conditions, the flue gas temperature at the inlet of the denitration system is lower than the normal working temperature of the catalyst. In order to ensure the reliable input of the denitration system, a bypass flue and an adjustment damper are added to the boiler economizer. Configure control logic and actual debugging to realize automatic control of the inlet temperature of the denitration system, and ensure that the denitration system can be continuously operating when the boiler is running in the 30%-100% load range.

At present, environmental protection requirements are getting stricter, almost all the boiler equipment of thermal power plant units have completed the desulfurization, denitration and electrostatic precipitator transformation to meet the pollutant emission standards. The desulfurization and electrostatic precipitator can be used during all load range, however, due to the chemical reaction principle, the denitration system cannot running in low load conditions.

In recent years, the flue gas denitration technology widely used in coal-fired power plant boilers is selective catalytic reduction (SCR). Economizer is the last heated surface of the boiler before the air heater, and the purpose is to reduce inlet flue gas temperature of the air preheater and save fuel.

The denitration system is arranged between the economizer and the air heater. Generally, the operating temperature of the catalyst used in the selective catalytic reduction reaction is between 300-400℃. The catalyst will not play its due role beyond the temperature range. In the design of conventional boilers, there will be the following problems: when the boiler is operating under high load conditions, the flue gas temperature at the inlet of the denitration system is just within the normal operating range of the catalyst; however, the normal operating temperature of the catalyst cannot be met when the boiler load is low. If the design is changed to increase the flue gas temperature at the inlet of the denitration system to meet the catalyst requirements under low load conditions, the overall flue gas temperature of the boiler will be further increased during high-load operation, resulting in high flue gas temperature, low boiler efficiency and large coal consumption. Therefore, according to the traditional design, the denitration system cannot be put into operation when the boiler is running under low load condition, but this has not been able to meet the requirements of the latest nitrogen oxide emission index.

In order to solve the contradiction that the flue gas temperature at the inlet of the denitration system at low load does not meet the working conditions of the catalyst, the
methods adopted by each coal-fired power plant are roughly divided into four types: setting a bypass flue, setting an economizer bypass, economizer classification, and returning hot steam extraction supplements feed water heating, which the first two methods are the most commonly used. This study introduces a technical scheme for setting bypass flue, and designs the control logic according to the actual operation of the boiler, realize automatic control of the inlet temperature of the denitration.

1 Transformation plan and problems

In the actual project construction, a hole is made in the flue at the economizer inlet, and part of the flue gas is pumped to the entrance of the denitration system, which is the bypass flue of the economizer, as shown in Fig. 1. When the boiler is at low-load operation, the flue gas at the inlet of the denitration system can reach a temperature above 320 °C by mixing flue gas which is higher temperature from the economizer outlet. Install the electric flue damper on the economizer outlet and the bypass flue to adjust the flue gas temperature at the inlet of the denitration system.

![Figure 1. Schematic diagram of installing a bypass flue in the boiler economizer.](image)

After investigation, most of the boilers that have been installed with economizer bypass flues, most of the bypass dampers are manually controlled, and manual adjustments are required when the load changes. Even in the automatic mode, the bypass damper and the flue damper are operated separately, and the flue gas temperature which is at inlet of the denitration system is the large inertia object. The control quality is poor during the low load period of the boiler. There will be a dynamic deviation which is easy to cause the furnace pressure fluctuation, when the load of the unit changes rapidly.

2 Ways to improve

2.1 Equipment installation and control system design

Generally, the cross-sectional area of the flue outlet of the boiler economizer in a power plant is relatively large. Two or more actuators can be used to drive the flue damper, which need to accept the same control command. The flue damper keeps fully open when the boiler is operated under high-load conditions. When the boiler is operated under low-load conditions, the flue gas temperature at the inlet of the denitration system begins to decrease. It needs to be regulated to ensure the continuity of the flue gas flow of the bypass flue, reduce the heat exchange of the economizer, increase the inlet temperature of the denitration system, and ensure the continuous and stable operation of the denitration system. The control logic is configured in the distributed control system (DCS) of the unit, the single loop proportional-integral-derivative (PID) control and corresponding logic function blocks are used to realize the control function.
2.2 Design of automatic control system

Install three thermocouples at the appropriate position at the inlet of the denitration system to measure the temperature of the flue gas. The thermocouples are connected to the DCS, the average value of the three measurement signals is taken as the adjusted variable of the automatic control system. The attendant manually set the target value of the flue gas temperature at the inlet of the denitration system. In the automatic mode, the deviation between the measured value and the set value is adjusted by the PID to control the opening of the bypass damper and the flue damper. In the manual mode, the two dampers can accept different commands from the attendant.

2.3 Control function design

The boiler flue gas temperature at the inlet of the denitration system generally meets the set value required by the catalyst when the boiler is operating at 60% or above load. At this time, the bypass damper is all closed, the flue damper is all opened, the flue gas is all passed through the economizer.

In the automatic mode, if the measured value of the flue gas temperature at the inlet of the denitration system is lower than the set value, the command output by the PID controls the bypass damper to increase the opening degree, if the bypass damper is fully opened the flue gas temperature at the inlet of the denitration system is still lower than the set value, the flue damper starts to close which is order to force the bypass flue increase the flue gas flow and reduce the heat exchange with the economizer. The system stops adjusting and stabilizes under a certain working condition when the deviation is equal to 0. If the measured value of flue gas temperature at the entrance of the denitration system is higher than the set value required by the system, the automatic system will act in the opposite direction as described above.

2.4 Calculation of scale factor and bias

The automatic control system uses a PID to control the bypass damper and the flue damper. Under the same working conditions, the adjustment directions of the two dampers are opposite and have a sequence, perform proportional and offset operations on the value output by the PID, as the control command of the bypass damper and the flue damper. The instruction C output by the PID is divided into two sections, the first section is 0 to 50 as the bypass damper working section, and the second section is 50 to 100 as the flue damper working section. The process of changing the PID output from 0 to 100 will be described below.

The first section serves as the bypass damper working section. When C changes from 0 to 50, the bypass damper should be gradually opened, and the opening command $C_b$ changes from 0 to 100. As the following formula

$$C_b = 2 \times C$$

Therefore, the scale factor of the bypass damper instruction is 2.

The second section is the working section of the flue damper. When C changes from 50 to 100, the flue damper should be gradually closed. The opening command $C_f$ changes from 100 to 0. Therefore, in the second section, set the scale factor to K, the bias is B. When C is equal to 50, $C_f$ is equal to 100, formula (2) is listed. When C is equal to 100, $C_f$ is equal to 0, formula (3) is listed, formula (2) and formula (3) form the equation system.
\[ K \times 50 + B = 100 \quad (2) \]
\[ K \times 100 + B = 0 \quad (3) \]

It is calculated that \( K = -2 \) and \( B = 200 \), so the scale factor of the flue damper control command is -2, and the bias is 200.

In actual engineering applications, the opening command of the flue damper and the bypass damper can only be between 0% and 100%, so the final output command value should be limited to 0 to 100. Through the segmentation processing of C, the segmentation control of the bypass damper and the flue damper is realized.

### 2.5 Tracking of the damper opening position

The automatic control system should keep the output signal from abrupt change at the moment of transferring between manual mode and automatic mode, so as not to cause fluctuation of the control system. In the automatic mode, the manual setting value of the two dampers should follow the feedback of the opening position of the two dampers in the field; while in the manual state, the system setting value should follow the change of the measured value of the controlled variable. By judging C, the control system can track the correct tracking value. In the automatic mode, when C is less than 50, it is determined to be the working section of the bypass damper, and the manual setting value should follow the feedback of the opening position of the bypass damper. When C is greater than 50%, it is judged to be the working section of the forward damper. The manual setting value should follow the change of the feedback of the opening position of the flue damper. In the manual mode, the automatic system setting value is also tracked according to this rule.

When the flue damper and the bypass damper are operating in automatic mode, the control system transfers to automatic operation mode. When control mode of any damper is transferred to manual, the control system will be forced to transfer to manual mode. Fig. 2 is the SAMA diagram of the logical configuration of the overall technical solution.

![Figure 2. The SAMA diagram of logic configuration of the automatic temperature control system.](image)
3 Application effect

The automatic system of denitration inlet temperature has achieved very good results. After the actual observation and test in field, the PID magnification and integration time are adjusted appropriately to ensure the continuous and fast response of the flue gas temperature which is at inlet of the denitration during the variable load of the boiler. Due to the introduction of integral action, the steady-state error of flue gas temperature at the inlet of the denitration system can be controlled within ±1°C. The specific application effect is shown in the fig. 3.

![Figure 3. Flue gas temperature curve of denitration inlet in automatic state.](image)

When the flue gas damper is faulty or overhauled, the logic of the control system can automatically determine the current working section, and accurately realize the set value tracking function, ensuring the system to switch between manual and automatic modes without interference.

4 Conclusion

The automatic denitration inlet temperature control scheme introduced in this study, which adopts a PID algorithm and completes the automatic coordination control of two or more dampers in the timing and direction through the additional calculation. The control logic is grouped in the DCS, it is easy to write and read. In the process of use, it can add some auxiliary functions according to the actual situation of the equipment. It has wide applicability and high reliability. It is suitable for denitration of boilers in thermal power plants under low-load conditions. The reliable input of the automatic control system will greatly reduce the labor intensity of personnel, and will further reduce the possibility of misuse of personnel leading to pollutant emissions exceeding the standard.

References

1. Guokun Xie;Kai Zheng; Yajuan Jia, MATEC Web of Conferences, Design of Fuzzy PID Temperature Control System, 228 (2018).
2. Zhang Yang, Yang Yonglong, Feng Qianwei, et al. Electric Power, Key technical issues of SCR denitrification from coal-Mired boiler flue gas, 48, 32(2015).

3. Wang Lele. Kong Fanhai. He Jinliang, et al. Thermal Power Generation, Difficulties and countermeasures of SCR denitration system operation in ultralow emission situation, 45, 19(2016).

4. Dong Chen, Wang Xiaobing, Niu Guoping. Thermal Power Generation, Application of economizer bypass on selective catalytic reduction system, 43, 96(2014).

5. Richard K L. International Journal of Chemical Kinetics, The NH3-NO-02 reaction, 315, 8(1976).