The Control System of Boiler Main Steam Temperature Based on Heat Transfer Calculation

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Abstract. The cascade PID control system used in the main steam temperature control of traditional thermal power plants has large hysteresis and large inertia characteristics. In order to solve the above problems, the program of heat transfer process of main steam and boiler flue gas is built based on Matlab. The amount of desuperheated water obtained by the program ensures that the main steam temperature of the boiler is the target temperature. Then the heat transfer calculation program is imported into the multi-model switching control system simulation platform based on heat transfer calculation built by Simulink. The results of simulation show that the multi-model switching control system based on heat transfer calculation solves the problem of large inertia and large delay of the main steam temperature successfully, and the control system can adapt to changes in boiler load.

1. Introduction

The temperature control of the main steam in most thermal power plant boilers still uses the traditional cascade PID control system, it is difficult to control the main steam temperature of the boiler accurately. The main circuit of the cascade PID control system mainly includes main regulator (PID controller), inert zone and main steam temperature transmitter, the role of main steam temperature transmitter is to eliminate the deviation between the actual temperature of the main steam and the target value[1]. In order to solve the problem that the control model does not match the parameters, researchers invented variable-parameter PID controllers that adjust the value of the parameter proportional differential integral in real time according to the difference between the controlled quantity and the target quantity, and improve the system control quality when the controlled model changes[2]. However, the criteria followed by the parameters of the PID regulator is still deviation or time linear functions, the main steam temperature cannot reach to the set value fundamentally [3]. For the above reasons, many researchers have studied the main steam temperature control system based on the prediction algorithm, Antonio Nevado [4] developed an adaptive predictive control system called Steam Temperature Optimizer (STO), The STO improved significantly the control precision and the stability of the steam temperature and confirmed adaptive predictive control as a reliable self-tuning methodology for this kind of process. Xiang-Jie and Dong Wenbo [5~6] proposed a nonlinear predictive fuzzy variable control system based on BP neural network algorithm, aiming at the
uncertainty of the system control model and the nonlinearity of the control object on the cascade PID temperature control system, the experimental and simulation results verify that the method can control the steam temperature better than the linear control algorithm. Ray T K[7] determined the optimization path through the exergy analysis of the two-stage SH attemperator with real-time operating parameters, which is beyond the scope of the traditional first law-based analysis. Strategies to minimize exergy destruction by suitably varying the proportions of stage I and stage II spray flows are established. The current research control method is mainly to estimate the calculation based on the operating parameters, this paper will improve the accuracy of control based on thermodynamic calculation.

2. The calculation program of boiler main steam heat transfer system

In the case of the known main steam inlet temperature of the screen superheater, the outlet main steam temperature of the screen superheater is taken as the inlet temperature of the high temperature superheater, the heat transfer calculation of it is divided into the hot section and cold section of high temperature superheater and cold section of desuperheated water, this gives the amount of desuperheated water required to maintain the main steam temperature at the set point. The main steam temperature heat transfer system is divided into five parts: fuel combustion, furnace heat transfer, screen superheater, high temperature superheater and desuperheating water calculation.

This paper modularize the boiler main steam heat transfer system based on Matlab. The whole module is divided into calculation module, heat transfer unit and auxiliary module, and the calculation module is divided into physical parameters, exothermic calculation, furnace calculation, and the heat transfer unit is divided into convection heating surface, semi-radiation heating surface and desuperheating water calculation. On the basis of the model analysis, use the modular programming method to complete the programming of calculation system. Finally, combine the modules and connect the heat transfer unit modules in the order of calculation to form the boiler main steam heat transfer calculation system.

3. The multi-model switching main steam temperature control system based on heat transfer calculation

The controlled object in the attemperator control system is divided into two parts: the part before desuperheating is called the leading area, and the part after desuperheating is called the hysteresis area. In this paper, the transfer function of the leading and inert zones of the main steam control system is simplified to a first-order inertial plus pure lag transfer function. The transfer function of the leading area can be expressed as (1):

\[ G_{01}(S) = \frac{K_1}{(1+T_1S)^n} \]  

The transfer function of the overheated temperature is:

\[ G_0(S) = \frac{K_0}{(1+T_0S)^n} \]  

The transfer function of the inert zone is:

\[ G_{02}(S) = \frac{K_2}{(1+T_2S)^n} \]  

Where K is the amplification factor, T is the time constant, and n is the order. The above parameters of the lead area can be obtained through experiments, the calculation formula for the inertia transfer function can be expressed as (4)–(6):

\[ K_2 = \frac{K_0}{K_1} \]
\[
T_2 = \frac{n_0T_0^2 - n_1T_1^2}{n_0T_0 - n_1T_1}
\]

(5)

\[
T_2 = \frac{\left( n_0T_0 - n_1T_1 \right)^2}{n_0T_0 - n_1T_1}
\]

(6)

Taking the case of 30% boiler load as an example, the transfer function of the leading area is \( \frac{8.07}{(24s+1)^3} \), the transfer function of the inertia region is \( \frac{1.48}{(46.6s+1)^3} \), as shown in Figure 1, the equivalent first-order inertia plus pure lag transfer function is \( \frac{1.48}{108.5s+1} e^{-85s} \).

**Figure 1.** Generalized control system model under 30% load condition

The control system described herein couples the heat transfer process to conventional PID control and introduces switching function into it. The switching function switches the boiler controlled object to the closest corresponding typical load control model according to the calculation of the multi-model switching index, so that the control parameters can match with the model to achieve the desired control effect. The simulation system shown in Figure 2 is built under the condition of 30% load, it consists of a heat transfer calculation system and a multi-model switching system. The input parameters of the heat transfer calculation system are structural parameters and operating parameters, and the amount of desuperheated water is calculated through combustion and heat balance; When the boiler load changes, the switch written by the S function is used to switch between models.
4. Simulation of multi-model switching main steam temperature control system based on heat transfer calculation (JD-PID)

The simulation results of the JD-PID main steam temperature control system under five typical load conditions are shown in Figure 3. When the boiler load changes, the multi-model switcher switch to the control model that matches the current control model to obtain the ideal control results. Simulation results verify the effectiveness of the multi-model switching system. As the boiler operating load increases, the response time of the control system and the time to reach steady state are shortened. When the operating load of the boiler decreases, the system can reduce the overshoot effectively.

![Diagram](image-url)  
**Figure 2.** System based on heat transfer calculation under 30% load condition

![Graph](image-url)  
**Figure 3.** Simulation of JD-PID main steam temperature control system under typical load conditions
Figure 4 shows the step response curve of the boiler operating at 50% load. The multi-model switcher will switch at the beginning of the simulation and switch to the boiler load model closest to the 50% load accurately, the simulation results verify the accuracy of the model switch.

![Figure 4. Simulation of JD-PID main steam temperature control system under 50% load condition](image)

The above simulation curve shows that when the system is running in the initial stage, the system runs under the 30% load control model. Since the running load is not the typical load, model switching multiple times, after the system is running for about 200s, the system switch to the 44% control model automatically and then output the best correction factor, as the controlled object gets closer to the 44% load control model, thereby the main steam temperature is stabilized.

According to the above simulation results, the control effect of the main steam temperature control system based on heat transfer calculation is better than that of the cascade PID control system, mainly because the system can quickly eliminate the disturbance of the system.

5. Conclusion
This paper modularize the boiler main steam heat transfer system and coupled with the multi-model system switching control system to establish the JD-PID main steam temperature control system. The system not only quickly eliminates disturbances in the control system, but also matches the control model to controller parameters. The simulation results under typical load conditions show that as the boiler operating load increases, the response time of the control system and the time to reach steady state are shortened. When the operating load of the boiler decreases, the system can reduce the overshoot effectively; under atypical load conditions, the control system can switch models to approach boiler load continuously.

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