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Analysis of boiler main steam temperature control system with multi-model switching

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Abstract. The paper analyzes the main steam temperature of the boiler with multi-model switching control based on the PID control system. According to the calculation result of the multi-model switching index, when the boiler load changes, the switcher will switch the controlled object of the boiler to the closest corresponding control model under the typical load. Moreover, the function of the leading zone and the function of the inertia zone of the PID control system are integrated into an equivalent first-order inertia plus pure lag function. Comparing these two methods, it is concluded that the control system with the first-order inertia plus pure lag function has a better control effect.

1. Introduction

With China's power generation industry developing rapidly and the increasing demand for electrical energy, the goal of China's power development is the large grid, large units and highly automated boilers. The thermal power generating units have gradually evolved from small capacity in the past to high-parameter, large-capacity unit units, so that the main steam temperature control of the boiler have become more and more important ^[1]. The generator set of the thermal power plant will be large capacity and high parameters, so automatic and precise control of the T_{mst} of the boiler will be more and more important, and its control accuracy will be higher and higher. However, for the control of the T_{mst} of the boiler, PID control system is still widely used ^[2,3]. When using the PID control algorithm to control the T_{mst} , the control system is divided into primary and secondary circuits. The secondary regulator, pilot area and pre-conductor temperature transmitter make up the secondary circuit of the cascade PID control system. And the main circuit of the cascade PID control system mainly includes a



main regulator (generally a PID controller), an inert zone and a T_{mst} transmitter. Its role is to eliminate the deviation between the actual temperature of the main steam and the target temperature, so that the main steam temperature is stabilized near the target value or is the target value, ensuring safe, stable and economical power production.

Nomenclature

T_{mst} main steam temperature($^{\circ}\text{C}$)

2. Analysis of boiler main steam temperature control system

2.1. The cascade PID main steam temperature control system

A main controller and a sub controller constitute the cascade PID main steam temperature control system. Additionally, the output of the main controller is the input value of the sub controller. When this system is applied to boiler control, the main controller link is a fixed value control system, and the sub controller is a follower system that changes with the output of the main controller. The controller parameters of this paper are optimized by Simulink's PID controller module. The following is an example of 30% boiler load conditions to illustrate the optimization of the sub-regulator parameters. The control system is shown in Figure 1. The controller adopts the P controller, and the control object is the transfer function of the inert zone and the leading zone. As shown in Figure 1, Transfer Fcn1 is the conduction function of the leading zone, and Transfer Fcn2 is the transfer function of the inert zone.

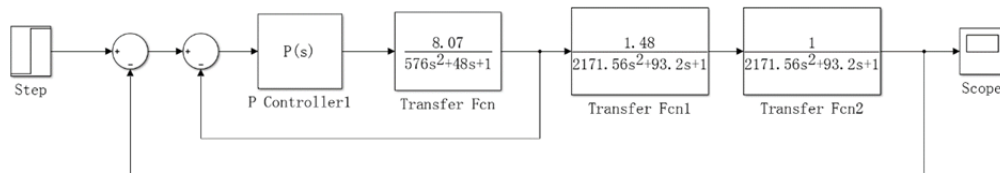


Figure 1. T_{mst} P controller control system under 30% load condition

2.2. Theoretical analysis of multi-model switching main steam temperature control system

Many disturbances affecting the T_{mst} of the boiler reach a stable value, such as the temperature, pressure and discharge of the superheated steam, wherein the discharge of the superheated steam has the greatest influence on T_{mst} . The temperature and pressure of the superheated steam interact with each other, and the change in the discharge causes the pressure to change, which in turn causes the temperature to change. Therefore, the change of boiler load is the main reason for the change of the controlled object model of the control system.

The reason why the traditional cascade PID main steam temperature control system cannot control the T_{mst} is that the PID controller adjusts the system control parameters according to a certain operating point control model. When the boiler working load changes, the control model of the T_{mst} changes greatly. If the initial PID controller parameters are used to control the boiler operation model, the control effect will be deteriorated, and even the instability of the control system will be caused. Therefore, for the purpose of control the T_{mst} of the boiler more efficiently, it is prerequisite to adjust the control object model and the model matching controller parameters under the typical or corresponding conditions, and it is also important to optimize the corresponding control parameters.

According to the calculation of the multi-model switching index, when the boiler load changes, the switcher switches the boiler controlled object to the closest corresponding typical load control model to achieve the perfect control effect.

2.3. Analysis of boiler operating conditions

According to the maximum load design capacity and main operating load interval of the unit, five typical operating conditions were divided, and each typical operating point represented load value. Using the actual operating data of the typical working condition of the boiler, the mathematical model of the T_{mst} at the typical operating point was tested to achieve the purpose of multi-model switching. The transfer function between the leading and inert zones of the boiler under typical load conditions was shown in Table 1.

2.4. First-order inertia plus pure lag function of the T_{mst} model

In the paper, the transfer function of the leading and inert zones of the main steam was simplified to a first-order inertia plus pure hysteresis transfer function. In the following, this main steam temperature control system was referred to as J-PID for short. Through the leading and inactive zone functions, the next-order inertia plus pure hysteresis function of five typical load conditions of the boiler was obtained.

Table 1. Main steam temperature lead zone and inert zone under equivalent load conditions and equivalent first-order inertia plus pure lag model

Boiler load	Leading zone	Inert zone	Equivalent first-order inertia plus pure lag
30%	$\frac{8.07}{(24s+1)^2}$	$\frac{1.48}{(46.6s+1)^4}$	$G_m = \frac{1.48}{108.5s+1}e^{-85s}$
44%	$\frac{6.62}{(21s+1)^2}$	$\frac{1.66}{(39.5s+1)^4}$	$G_m = \frac{1.66}{93.02s+1}e^{-70s}$
62%	$\frac{4.35}{(19s+1)^2}$	$\frac{1.83}{(28.2s+1)^4}$	$G_m = \frac{1.83}{55s+1}e^{-65s}$
88%	$\frac{2.01}{(16s+1)^2}$	$\frac{2.09}{(22.3s+1)^4}$	$G_m = \frac{2.09}{48.9s+1}e^{-44s}$
100%	$\frac{1.58}{(14s+1)^2}$	$\frac{2.45}{(15.8s+1)^4}$	$G_m = \frac{2.45}{30.5s+1}e^{-35s}$

3. Simulation comparison of PID control system under five typical conditions in boiler

The model in the computer simulation of the main steam temperature control system with PID and the first-order inertia plus pure lag function (in the figure is the J-PID curve) under five different conditions was given.

Five simulation results under different conditions in two systems were shown in Figures 2 to 6 below:

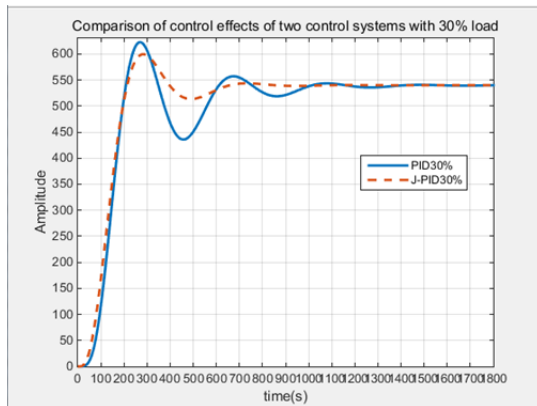


Figure 2. 30% boiler load

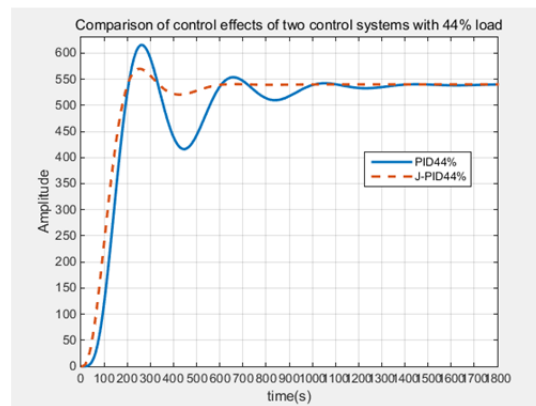


Figure 3. 44% boiler load

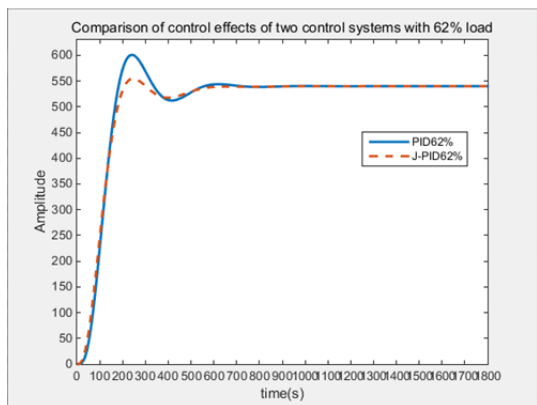


Figure 4. 62% boiler load

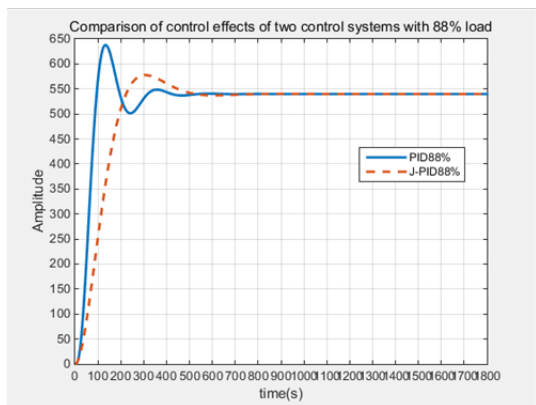


Figure 5. 88% boiler load

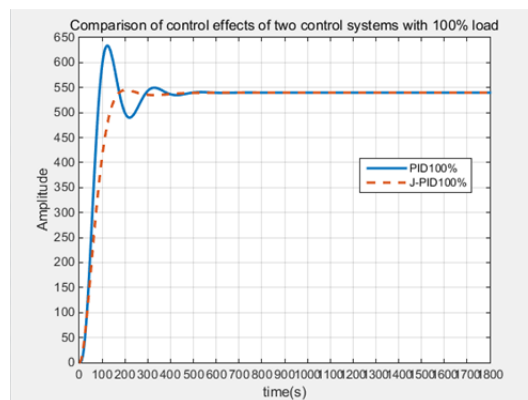


Figure 6. 100% boiler load

Based on the comparison of Figures 2 to 6, it could be concluded that:

When the boiler was operated under low load conditions (30% and 44%), the T_{mst} exhibits large hysteresis and large inertia, and the response time of the system was longer, so the time main steam temperature reaching steady was longer. The control system with the first-order inertia plus pure lag function had a less overshoot than the original PID control system. The higher the load was, the less the overshoot was. Just at the time the boiler was running at the full load (100%), the control system with the first-order inertia plus pure hysteresis function had almost no overshoot. In addition, the time to reach the T_{mst} to reach the set temperature was also significantly faster in this control system.

4. Conclusion

In the main steam temperature control system of the boiler, compared with the ordinary cascade PID control system, the control system with multi-model switching has a better control effect. In addition, this paper integrates the function of the leading zone and the function of the inert zone in the cascade PID control system into an equivalent first-order inertia plus pure lag function to optimize the control system with multi-model. The results of the simulation show that the improved control system has a small overshoot, and the time to reach the set T_{mst} is also decreased, thus the control effect gets better.

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