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Fuzzy Control of Boiler Superheated Steam Temperature

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ABSTRACT : *In this paper, a Fuzzy-PID model is established for superheated steam temperature of a 600 MW supercritical boiler. When the boiler load changes and step disturbance is added, the fuzzy-PID model is simulated and compared with the conventional PID control. The results show that this Fuzzy-PID control is efficient over a wide operation range, and has better performance than the conventional PID control system.*
KEYWORDS *-Fuzzy-PID, Steam temperature control, Boiler superheated steam temperature*

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I. INTRODUCTION

Superheated steam temperature is important to the safe and economic operation of power plant boiler unit. The conventional PID control is difficult to meet the control quality of the superheated steam temperature with large inertia and large delay [1, 2]. Fuzzy control is a non quantitative and fuzzy algorithm; it can adapt to the control of complex objects and improve the control quality [3, 4]. In this paper, a Fuzzy-PID model is established for a 600 MW supercritical boiler, of which the control effect is tested and compared with conventional PID control.

II. PID CONTROL OF BOILER SUPERHEATED STEAM TEMPERATURE

Boiler superheated steam temperature control is to keep the steam temperature within a certain range. Generally, the fluctuation of steam temperature shall not exceed ±(5~10)℃, and it is better within ±5℃. As the saturated steam is sent out from the boiler drum, and the superheated steam is required by the steam turbine or other users, the outlet pipeline of the boiler drum steam is equipped with superheater, which is used to heat the saturated steam to superheated steam with a certain temperature. After the saturated steam passes through the superheater, its temperature often exceeds the temperature required by the load. Therefore, a desuperheating device is set on the steam pipeline to control the outlet temperature of the superheater by regulating the flow of desuperheating water.

Because of the large delay and time constant of steam temperature, if the desuperheating water flow is only changed according to the deviation of steam temperature at the outlet of superheater, the steam temperature cannot be effectively controlled, so the control of single loop is difficult to meet the control requirements. At present, the improved method is to divide the superheater into two sections, and add an element testing desuperheater outlet temperature in the middle to form a cascade steam temperature control mode. Its structure is shown in Figure 1, and the control block diagram is shown in Figure 2 [5].

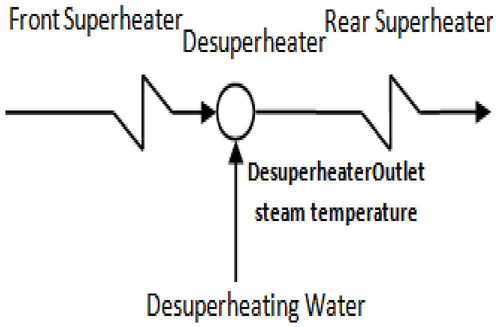

Figure1 Spraydesuperheating system

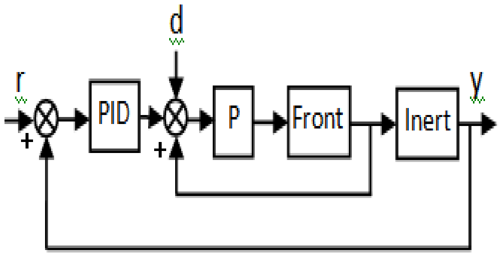

Figure2 Cascade PID control system

In this cascade control system, the front superheater and Desuperheater are called the front area, and Rear Superheater is called the inert area. When the outlet temperature of the desuperheater changes, the P regulator of the auxiliary regulator will change the opening of the desuperheating valve, change the flow of desuperheating water, initially maintain the steam temperature at the inlet of the rear superheater, and roughly regulate the main steam temperature at the outlet of the rear superheater. The main steam temperature at the outlet of the rear superheater is controlled by the PID of the main regulator. As long as the steam temperature at the outlet of the rear superheater does not reach the set value, the output of the main regulator will constantly change, so that the auxiliary regulator will constantly change the flow of desuperheating water until the main steam temperatrre returns to the set value. This control scheme improves the control accuracy of the main steam temperature.

III. FUZZY CONTROL OF BOILER SUPERHEATED STEAM TEMPERATURE

3.1 Design of fuzzy-PID controller

In the fuzzy control scheme, the main steam temperature deviation e and deviation change rate ec are selected as the input, and the proportion, integral and differential parameters Δkp, Δki and Δkdare selected as the output. As shown in Figure 3, the input e and ec is fuzzified into fuzzy variables E and EC by the factor K1 and K2, the fuzzy variables ΔKP, ΔKI and ΔKD of the output are obtained by reasoning, and the accurate variables Δkp, Δki and Δkd of the output are obtained by factor K3, K4 and K5 [6].

The fuzzy fields of input E, EC and output ΔKP,ΔKI, ΔKD are divide into seven fuzzy sets NB(negative big), NM(negative middle), NS(negative small), ZO(zero), PS(positive small), PM(positive middle), PB(positive big). The trigonometric membership function is adopted, as shown in Figure 4.

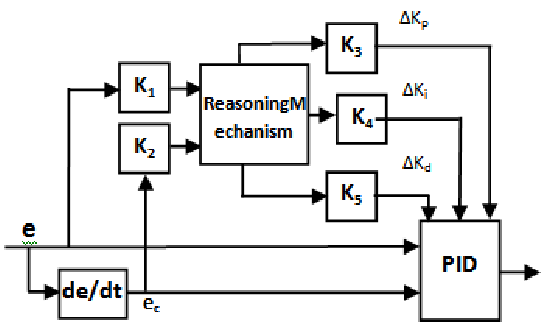

Figure3 Structure of fuzzy controller

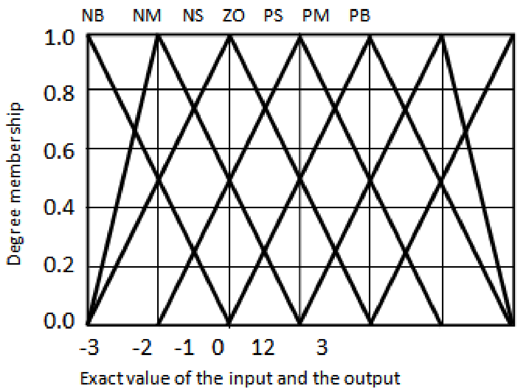

Figure4 Membership function of input and output

E and EC belong to 7 fuzzy sets. The fuzzy rules for determining their corresponding output ΔKP, ΔKI and ΔKD are listed in Table 1, Table 2 and Table 3.

TABLE1 Fuzzy rule table of ΔK_P

E / C	NB	NM	NS	ZO	PS	PM	PB
NB	PB	PB	PM	PM	PS	ZO	ZO
NM	PB	PB	PM	PS	PS	ZO	NS
NS	PM	PM	PM	PS	ZO	NS	NS
ZO	PM	PM	PS	ZO	NS	NM	NM
PS	PS	PS	ZO	NS	NS	NM	NM
PM	PS	ZO	NS	NM	NM	NM	NB
PB	ZO	ZO	NM	NM	NM	NB	NB

TABLE2 Fuzzy rule table of ΔK_I

E / C	NB	NM	NS	ZO	PS	PM	PB
NB	NB	NB	NB	NM	NS	ZO	ZO
NM	NB	NB	NM	NM	NS	ZO	ZO
NS	NB	NM	NS	NS	ZO	PS	PS
ZO	NM	NM	NS	ZO	PS	PM	PM
PS	NM	NS	ZO	PS	PS	PM	PB
PM	ZO	ZO	PS	PS	PM	PB	PB
PB	ZO	ZO	PS	PM	PM	PB	PB

According to the fuzzy rule table, we can get the fuzzy sets of ΔKP,ΔKI, ΔKD at every time, and then get the parameters of the fuzzy PID controller.

3.2 Fuzzy control of superheated steam temperature

The superheated steam temperature adopts the cascade control mode , and its principle is shown in Figure 5. The main regulator adopts the fuzzy-PID controller, and the auxiliary regulator adopts the proportional regulator.

TABLE3 Fuzzy rule table of ΔK_D

E / C	NB	NM	NS	ZO	PS	PM	PB
NB	PS	NS	NB	NB	NB	NM	PS
NM	PS	NS	NB	NM	NM	NS	ZO
NS	ZO	NS	NB	NM	NM	NS	ZO
ZO	ZO	NS	NS	NS	NS	NS	ZO
PS	ZO	ZO	ZO	ZO	ZO	ZO	ZO
PM	PS	ZO	NS	NM	NM	NM	NB
PB	ZO	ZO	NM	NM	NM	NB	NB

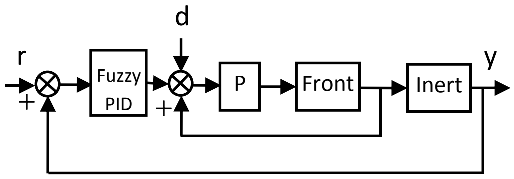

Figure 5 Fuzzy PID control system

Ⅳ. CONTROL ALGORITHM SIMULATION

The simulation object is the superheated steam temperature system of a Supercritical 600 MW boiler. The transfer function of the steam temperature of four typical loads of the system to the disturbance response of desuperheating water is shown in Table 4 [1, 7, 8].

TABLE4 The transfer function ofthe steam temperature

load%	front area	inert area
37	$-\frac{5.072}{(1+28s)^2}$	$\frac{1.048}{(1+56.6s)^8}$
50	$-\frac{3.067}{(1+25s)^2}$	$\frac{1.119}{(1+42.1s)^7}$
75	$-\frac{1.657}{(1+20s)^2}$	$\frac{1.202}{(1+27.1s)^7}$

100	$-\frac{0.815}{(1+18s)^2}$	$\frac{1.276}{(1+18.4s)^6}$

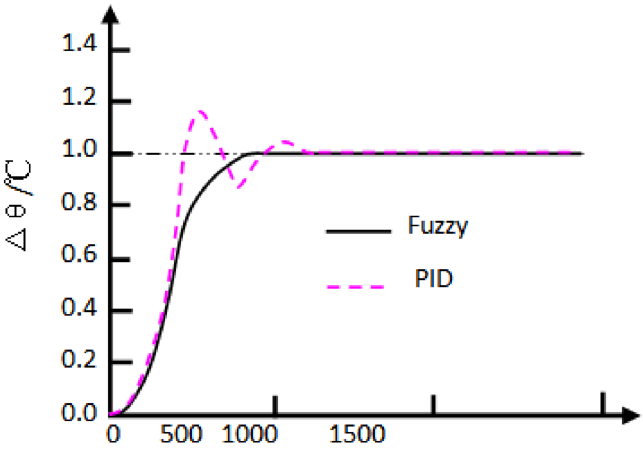

Figure 6 Steam temperature response set at 75% load

In order to test the control effect of fuzzy-PID control, it is compared with the conventional PID control system, and the steam temperature response curve is shown in Figure 6, 7, 8, 9.
As shown in Figure 6, the PID parameters are set at 75% of the load, and the adjustment time and overshoot of fuzzy control are better than that of conventional PID control.
As shown in Figure 7, 8 when the load changes, the fuzzy control shows good adaptability. The oscillation and adjustment time of the conventional PID control increase.

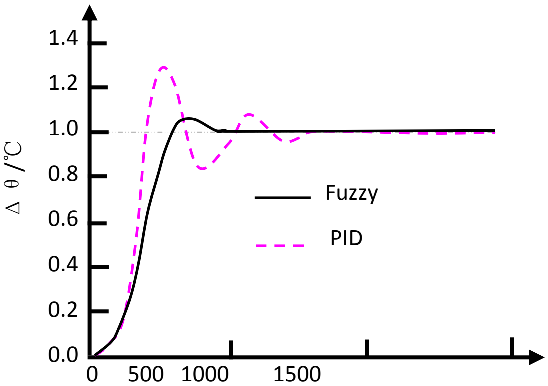

Figure 7 Steam temperature response at100% load

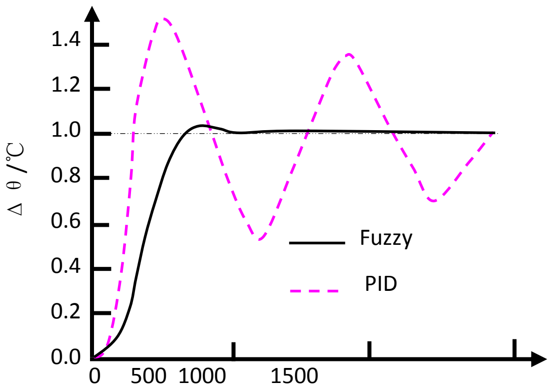

Figure 8 Steam temperature response at37% load

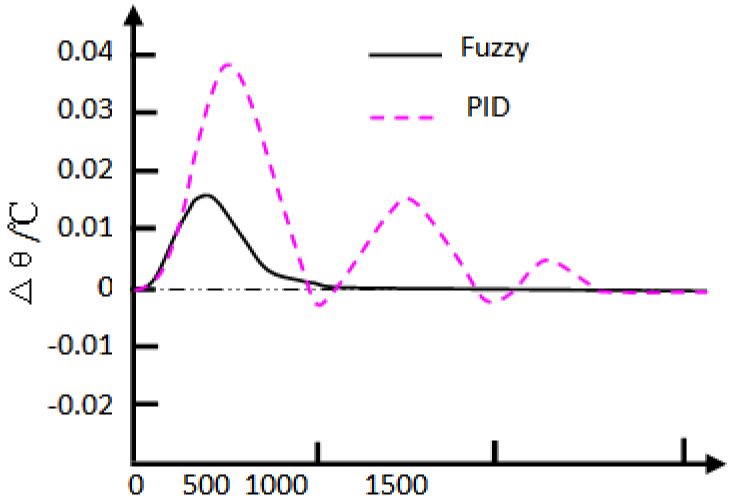

Figure 9 Response of Steam temperature to step disturbance

Under zero initial condition, the control effect of the fuzzy control and the conventional PID control is compared when the disturbance makes step change, as shown in Figure 9. It can be seen from the figure that the influence of disturbance on the steam temperature is smaller by using fuzzy control than by using conventional PID control, which shows that the anti disturbanceability of fuzzy control is better than that of conventional PID control.

V. CONCLUSION

The fuzzy control scheme is applied to the boiler steam temperature control. The dynamic simulation results show that the fuzzy control has better control quality and better adaptability than the conventional PID control for a large range of load and disturbances. It shows that the fuzzy control scheme has positive significance for improving the quality of boiler steam temperature control.

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