Self Tuning PID Controller for Main Steam Temperature in the Power Plant

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Abstract. In this paper, a PID self-tuning controller is used for the control of main steam temperature in the power plant. A common weakness of these self-tuning PID controllers is their inability to cope with dead time processes. In this paper, self-tuning controller based on pole assignment approach, which can overcome constant and known dead time is used and the results show that the controller works well in handling dead-time process.

Keywords: Self-tuning PID controller, Smith predictor, Dead-time, Main steam temperature, Power plant.

1 Introduction

Many industrial processes inevitably change over time for a variety of reasons that include: equipment changes, different operating conditions, or changing economic conditions. Consequently, a fundamental control problem is how to provide effective control of complex processes where significant process changes can occur, but cannot be measured or anticipated. The main steam temperature controlled process in the power plant is a typical process with nonlinear, dead time, time-varying parameters and it is very difficult to control[1]. Traditionally, PID or PI controllers connected to the plant are tuned with a reduction of gain so that overall stability can be obtained. This results in poor performance of control. One of the most important events in the development of digital control systems is the introduction of the self-tuning controller for single variable systems [3]. The extension of the theory to multivariable systems has since been investigated extensively [4] , [5]. However, in the industrial sector, the process controllers in operation are predominantly PID type due to their simple and robust nature. Various types of self-tuning PID controllers have been proposed in the past. In this paper, a self-tuning pole assignment PID controller which can overcome known and constant dead, is used.

2 Pole Assignment Self-tuning PID

The original pole assignment self-tuning PID controller proposed by Wittenmark and Astrom is shown in Fig. 1. Assuming that the process can be described by the difference equation [2].

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$$Ay(z^{-1}) = Bu(z^{-1}) \tag{1}$$

With

$$A=1+ a_1 z^{-1} + a_2 z^{-2} \tag{2}$$

$$B = b_1 z^{-1} + b_2 z^{-2} \tag{3}$$

Given A, B, and

$$R = 1 + z^{-1} \tag{4}$$

$$Q = q_0 + q_1 z^{-1} + q_2 z^{-2} \tag{5}$$

$$Q(1) = q_0 + q_1 + q_2 \tag{6}$$

The closed-loop transfer function is given by

$$\frac{y}{y_r} = \frac{Q(1)B}{A(1-z^{-1})R + QB} \tag{7}$$

In order to obtain a closed-loop polynomial P, polynomials Q and R must satisfy the Diophantine equation

$$P = A(1-z^{-1})R + QB \tag{8}$$

The coefficients Q and R can be obtained by solving the simultaneous equations that follow

$$q_0 b_1 + r_1 + a_1 - 1 = p_1 \tag{9}$$

$$q_1 b_1 + q_0 b_2 + r_1 a_1 - r_1 - a_1 + a_2 = p_2 \tag{10}$$

$$Q(1) = q_0 + q_1 + q_2 \tag{11}$$

$$q_2 b_2 - r_1 a_2 = 0 \tag{12}$$

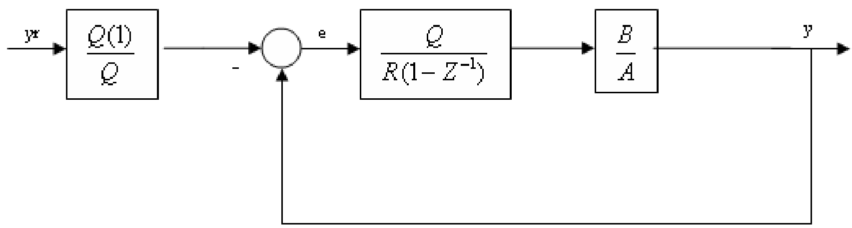

Fig. 1. Block Diagram of Pole Assignment Self-Tuning PID.

If $P = 1 + p_1 z^{-1} + p_2 z^{-2}$ is the desired characteristic equation, then controller parameters R and Q can be determined uniquely, provided A and B are coprime. The controlled variable can be determined by the relationship

$$(1 - z^{-1})Ru = Q(1)y_r - Qy \tag{13}$$

3 A Pole Assignment Self-tuning PID Controller with Smith Predictor Which Overcomes Constant Dead Time

Smith has proposed the idea of a predictor to overcome dead time by including a minor feedback loop at the output of the controller. The key idea is that the controller design can be assigned PID controller which incorporates the smith predictor is shown in Fig. 2.

Form Fig. 2, the controlled variable can be determined as follows [2]:

$$(1 - z^{-1})Ru = Q(1)y_r - Qy - Qu_1 + Qu_2 \tag{14}$$

In this configuration, closed loop stability is not affected by dead time as it can be shown that the controlled variable is independent of the delay. Since

$$u_2 = \hat{G}_p z^{-d} u \tag{15}$$

$$y = G_p z^{-d} u \tag{16}$$

$$u_1 = \hat{G}_p u \tag{17}$$

Then controlled variable

$$u = \frac{Q}{R(1 - z^{-1})}\left(\frac{Q_1}{Q} y_r - y + u_2 - u_1\right) = \tag{18}$$

$$\frac{1}{R(1-z^{-1})}\left(Q_1 y_r - Q\left(G_p z^{-d} u - \hat{G}_p z^{-d} u + \hat{G}_p u\right)\right)$$

If $G = \widehat{G_p}$ then

$$u = \frac{1}{R(1-z^{-1})}\left(q_1 y_r - Q\hat{G}_p u\right) \quad (19)$$

Since equation (19) does not include the dead time, then u is independent of dead time.

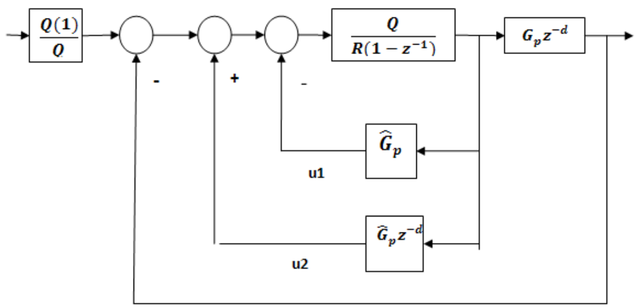

Fig. 2. Block Diagram of Pole Assignment Self-Tuning PID Controller with Smith Predictor.

4 Simulation

The process considered is the pulverized coal-firing 200MW steam-boiler unit used for electric power generation. It produces 670 tons of steam per hour at maximum continuous rating [1]. Two-stage sprayers were applied for the superheated temperature system in a multi-stage control manner to reduce the time constant of the plant and improve the control performance. The rated superheated steam temperature is 540°C. The task of the super heater in boiler-turbine system is to heat the steam by combustion gas and then send it to turbine[1].

As shown in Fig.4, the steam coming from the boiler drum passes through the low-temperature super heater and receives a spray water injection for protection before passing through the radiant-type platen super heater. The steam coming out from the radiant-type platen super heater receives a second spray water injection before passing through the high-temperature super heater. The super heater steam temperature reaches the highest point within the whole steam-water process and thus presents great influence on the safety and running efficiency of the whole power plant [1]. A properly control system by super heater water spray should maintain strictly the steam temperature within the permitted range (10°C in transient process and 5°C in steady state). Higher temperature could damage the super heater and the high-pressure-turbine by high heat strength. Lower temperature could decrease the running efficiency of the whole steam-boiler. By reducing temperature fluctuations, mechanical stress causing micro cracks is diminished, therefore the useful life of the plant is increased and maintenance cost is decreased [1]. The main steam temperature is an important parameter, which is related to the efficiency and safety of the power plant. However, it is affected by many disturbances such as load changing or combustion situation changing or flow of the spray water changing etc. The main steam temperature controlled process is a typical process with significant delay and time-varying parameters.

According to many experiments and, the main steam temperature controlled process can be described approximately as[1]

$$G(s) = \frac{0.4}{30s+1} e^{-2s} \tag{20}$$

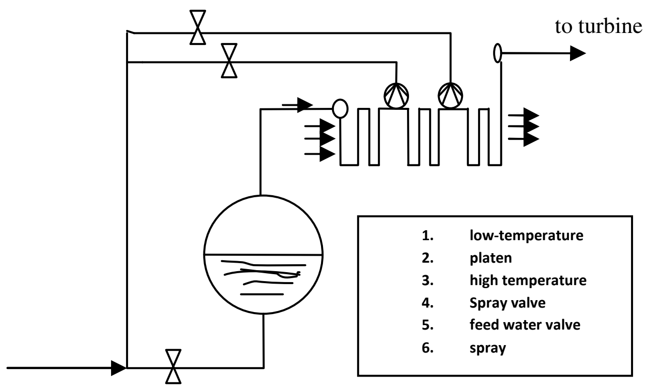

Fig. 3. The superheated steam system.

The presented controller is applied to the superheated steam and simulated by MATLAB/SIMULINK. The results are shown in figures (4-6).

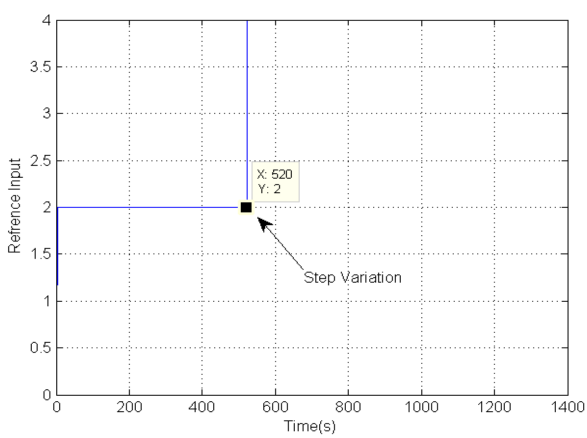

Fig. 4. Reference input.

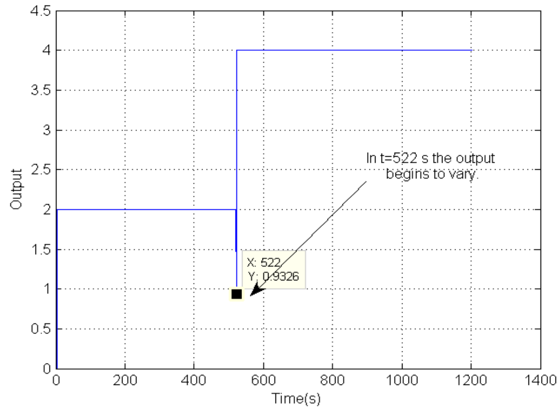

Fig. 5. Output of controlled superheated steam system..

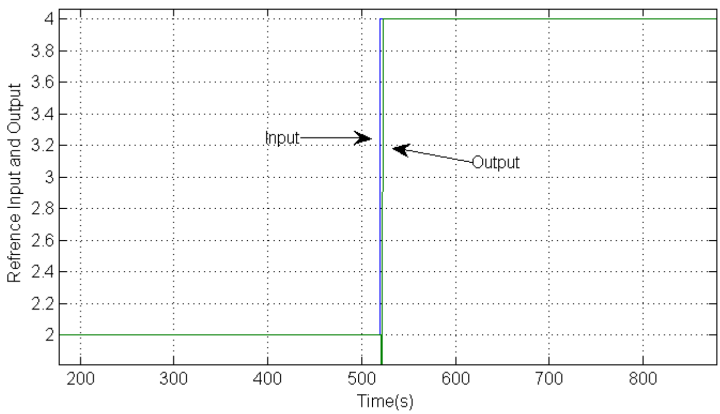

Fig. 6. The reference input and output of controlled superheated steam system.

Fig. 4 shows the reference input. Fig. 5 shows the response of the controlled system and Fig. 6 shows the reference input and output in a plot. The reference input increases to 4 at t=520 s and consequently the output increases to 4 with sharp undershoot and negligible settling time and overshoot.

5 Conclusion

A self-tuning PID controller based on the pole-assignment is designed to control the main steam temperature in the power pant in this paper. The constant and known dead time process can be controlled by the controller with a Smith predictor. The presented controller is applied to the superheated steam and simulated. the simulation results show that the proposed controller copes well with the dead time processes.

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