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Comparision of Smithpredictor, Sliding Mode and PID Controller For Steam Pressure in Coal-Fired Power Plant Boiler

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Abstract: *Since the combustion system of coal-fired boiler in thermal power plant is characterized as time varying, strongly coupled, and nonlinear, it is hard to achieve a satisfactory performance by the conventional proportional integral derivative (PID) control scheme. For the characteristics of the main steam pressure in coal-fired power plant boiler, the sliding mode control system with Smith predictive structure is proposed to look for performance and robustness improvement. First, internal model control (IMC) and Smith predictor (SP) is used to deal with the time delay, and sliding mode controller (SMCr) is designed to overcome the model mismatch. Simulation results show the effectiveness of the proposed controller compared with conventional ones.*

Keywords: *coal fired power plant boiler, combustion system, main steam pressure, sliding mode control, Smith predictor, internal model control*

I. Introduction

Thermal power plant boiler combustion system is a typical chemical process. Due to the existence of highly nonlinearities, uncertainties and load disturbances, the boiler is a complex component of the coal fired power plants [1-3]. To achieve reliable operation of this component, modern control engineering is extensively used in various configurations [4-7]. Although the steam production varies during plant operation, output such as steam pressure must be maintained at their respective values [8, 9]

Main steam pressure is one of the important parameters of boiler in thermal power plant. In traditional control strategy, the process model is required, either explicitly or implicitly. Nowadays, the main steam pressure control system of boiler in thermal power plant usually adopts conventional proportional integral derivative (PID) control scheme. The main steam pressure control system is a typical time delays system, which increase the difficulties to carry on effective control. Primarily, internal model control (IMC) [10-12] and Smith predictor (SP) [13, 14] are the control scheme used for time delay compensation. Actually, this approach is sensitive to modeling errors, since the design requires the use of a process model, which can be difficult to obtain in practice. When the load of power unit changes significantly, modeling errors are unavoidable to result in a mismatch between the model and the actual plant.

The sliding mode control (SMC) approach, which is one of the variable structure control, is a robust control technique [15-17]. At first, the sliding surface is designed to match plant uncertainties and external disturbances. And then a feedback control law is designed to reach the sliding surface at finite time. SMChas been used to design controllers based on its ability for dealing with model-plant mismatches [18].

This paper presents a design approach of sliding mode predictive control system (SMPC) for main steam pressure based on an approximate first order plus time delay (FOPTD) process model. Firstly, the predictive structure based on IMC and SP is used to deal with the time delay. A sliding mode controller based on predictive structure is designed to overcome the model mismatches. The effectiveness of the proposed method is verified by the simulation experiments of controlling the main steam pressure of a 300 MW coal-fired power plant boiler.

II. Boiler Combustion System

The combustion system of coal-fired power plant boiler is shown in Fig. 1. The main object of the combustion control system is to keep steam pressure stable and response the load changes rapidly, achieve optimum combustion efficiency and keep furnace negative pressure stable.

There are three control loops, including those for main steam pressure, excess air coefficient and furnace negative pressure. The input variables are coal mass flow rate, supply air flow rate and draft gas flow rate, and output variables are main steam pressure, excess air coefficient and furnace negative pressure, respectively The main object of the combustion control system is to keep steam pressure stable and response the load changes rapidly, achieve optimum combustion efficiency and keep furnace.

Steam is generated in the boiler under carefully controlled conditions. The steam flows to the turbine, which drives a generator for the production of electricity and for distribution to the electric system at the proper voltage. Since the power plant has its own electrical needs, such as motors, controls, and lights, part of the electricity generated is used for these plant requirements. The coal is put in the boiler after pulverization. For this pulverize is used. A pulverizer is a device for grinding coal for combustion in a furnace in a power plant. Generally, the dynamic model of the boiler combustion system can be written as

$$\begin{bmatrix} y_1(s) \\ y_2(s) \\ y_3(s) \end{bmatrix} = \begin{bmatrix} G_{11}(s) & 0 & 0 \\ G_{21}(s) & G_{22}(s) & 0 \\ 0 & G_{32}(s) & G_{33}(s) \end{bmatrix} \cdot \begin{bmatrix} u_1(s) \\ u_2(s) \\ u_3(s) \end{bmatrix} \quad (1)$$

y1(s), y2 (s) and y3 (s) are main steam pressure (MPa), oxygen content of flue gas and furnace negative pressure (Pa), respectively. u1(s), u2 (s) and u3 (s) are coal mass flow rate (kg·s−1), supply air flow rate (m3·s−1) and draft gas flow rate (m3·s−1), respectively.

Thus, the transfer function can be written as a first order plus time delay (FOPTD) process model:

$$G(s) = \frac{K}{1 + Ts} e^{-\tau s} \quad (2)$$

where K, T and τ are gain, time constant and time delay, respectively.

III. Indentations and Equations

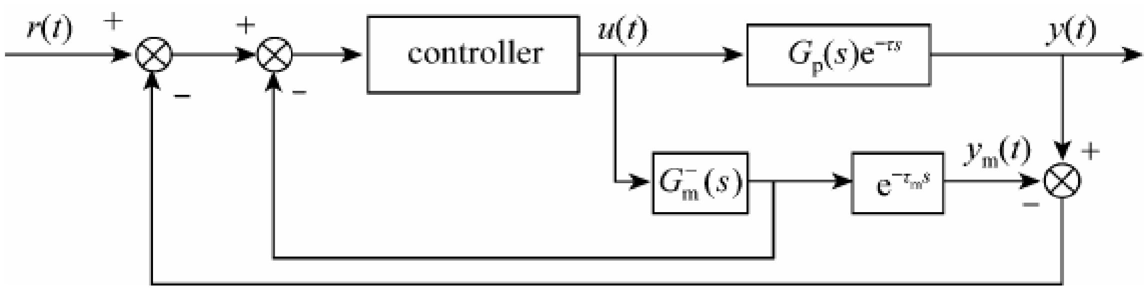

Fig. 1 Smith Predictor Structure

The Smith predictor structure is shown in Fig. 1, where y(t) is the process output, r(t) is the set point, Gm (s) − is the invertible part of process model and y_m (t)m the process model output.
The closed-loop transfer function of the system, coming from Fig. 2, can be written as

$$G(s) = \frac{G_C(s)G_p(s)}{1 + G_c(s)G_m^-(s) + G_C(s)\left[G_p(s) - G_m(s)\right]} \quad (3)$$

where Gc (s) , Gp (s) and Gm (s) are controller, process and model transfer functions, respectively. The linear function of the sliding mode control can be expressed as follows

$$s(t) = f\left[r(t), y_m(t)\right] \quad (4)$$

Where r(t) is the reference input and y_m(t) is the model output.

$$\dot{s} = 0 \quad (5)$$

The reaching law can be expressed as follows:

$$u(t) = \alpha \frac{s(t)}{|s(t)| + \beta} \quad (6)$$

where α is the tuning parameter responsible for the speed with which the sliding surface I reached, and β is used to reduce the chattering problem. this model can be represented in the following way:

$$G_m(s) = G_m^+ G_m^- \quad (7)$$

where Gm+ corresponds to the noninvertible term of the model, and Gm− is the free delay part. They can be represented as

$$G_m^+ = e^{-\tau s} \quad (8)$$

$$G_m^- = \frac{K}{Ts+1} \quad (9)$$

Let us propose the sliding surface

$$S(t) = e(t) \quad (10)$$

where e(t) is the error between the reference input r(t) and the free delay part of model output y_m (t) .From Eqs. (5) and (10), we can obtain

$$\frac{ds(t)}{dt} = \frac{dr(t)}{dt} - \frac{dy_m(t)}{dt} = 0 \quad (11)$$

From eq 2 put it into differential equation form, which represents the model:

$$T\frac{dr(t)}{dt} + y_m(t) = Ku(t) \quad (12)$$

$$u(t) = \frac{T}{K}\left[\frac{dr(t)}{dt} + \frac{y_m(t)}{T}\right] \quad (13)$$

From eq (6) and (13) the smith predictor scheme based on sliding controllers given by the following equation

$$u(t) = \frac{y_m(t)}{K} + \alpha\frac{s(t)}{|s(t)|+\beta} \quad (14)$$

The controller tuning parameters are determined using time domain performance methods, resulting in the following equation

$$\alpha = \frac{0.72}{|K|}\left(\frac{T}{\tau}\right)^{0.76} \quad (15)$$

$$\beta = 0.68 + 0.12|K|\alpha\frac{\tau+T}{\tau T} \quad (16)$$

Proof from eq (13)

$$\frac{ds(t)}{dt} = \frac{dr(t)}{dt} - \frac{dy_m(t)}{dt} = \frac{dr(t)}{dt} - \left[\frac{K}{T}u(t) - \frac{y_m(t)}{T}\right] \quad (17)$$

Substituting in equation (14), it is obtained

$$\frac{ds(t)}{dt} = -\lambda\frac{s}{|s|+\beta} \quad (18)$$

where $\lambda = K\alpha / T > 0$

Therefore, for all $t > 0$

$$s\dot{s} = s(t)\frac{ds(t)}{dt} = -\lambda\frac{s^2}{|s|+\beta} < 0 \quad (19)$$

Which shows that the sliding mode is reachable.

IV. Performance Analysis

In this paper, the main steam pressure of a 300 MW coal-fired power plant boiler is taken as the controlled plant. In order to simulate the boiler main steam pressure performance, the approximated model identified by real operation data from a 300 MW power plant boiler is obtained as follows: The input of the transfer function is the fuel mass flow rate, and its unit is kg·s−1, the output of the transfer function is main steam pressure of the boiler, and its unit is MPa

1) Sliding Mode Controller (SMC) with Smith Predicture (SP) Structure

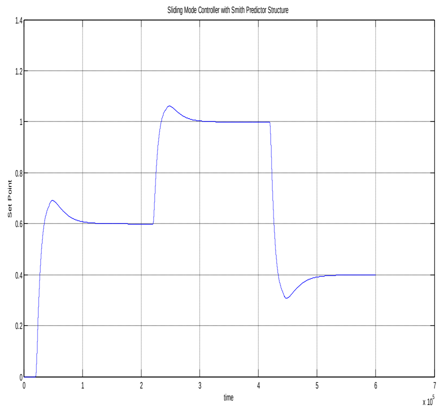

Fig. A Time response for set point of SMC and SP Structure

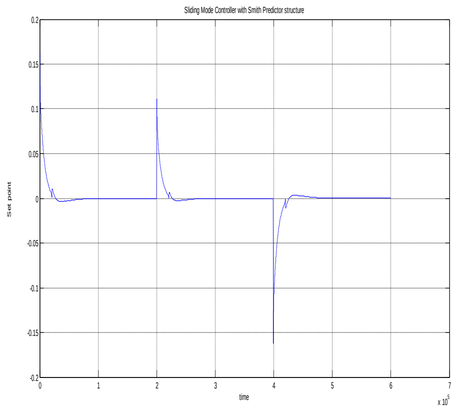

Fig B Time response for set point of SMC and SP Structure

2) Proportional Integral Derivative Controller PID with Sliding Mode Controller SMC

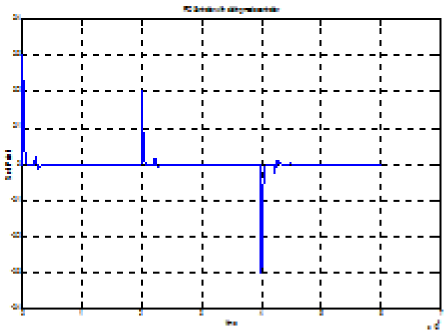

Fig A Time response for set point of PIDSMC

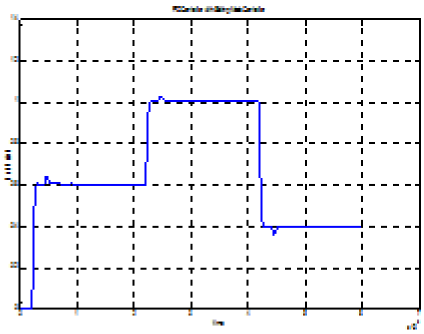

Fig B Time response for set point of PID & SMC

3) Predictive Sliding mode control

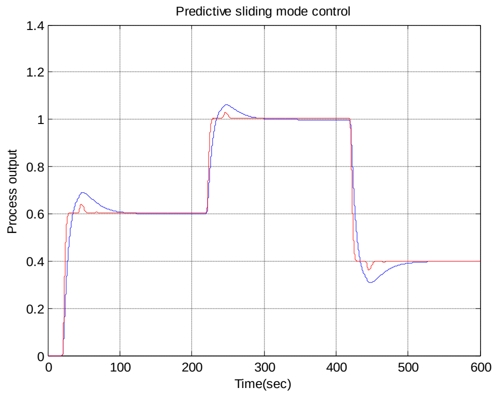

Fig A Time respone for Process Output of PSMC

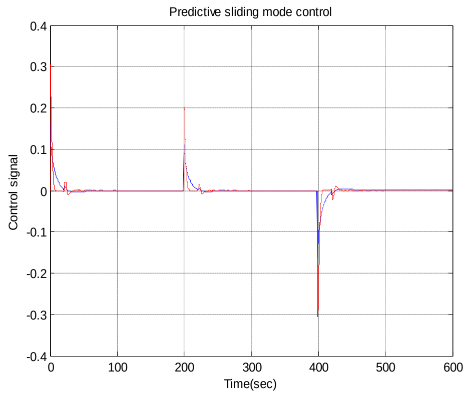

Fig B Time response for control signal of PSMC

V. Conclusion

In this paper, an approximate first order plus time delay (FOPTD) model of a boiler main steam pressure system is considered, in which the input variables is coal feed flow rate and the output is main steam pressure. After modeling, a combined approach of predictive structures with sliding mode control was presented. The predictive structures of IMC and SP are used to deal with time delay. The SMPC is proposed to overcome the model mismatch. This control approach showed the benefits for dealing with long time delay using the predictive structure plus the robustness of the sliding mode theory. The simulation results showed a better performance and robustness against set point changes when they were compared with classical PID control approaches.

References

[1]. Havlena, V.R., Findejs, J., "Application of model predictive control to advanced combustion control", Control Engineering Practice., 13 (6), 671-680 (2005).

[2]. Flynn, D., Thermal Power Plant Simulation and Control, IEE, London (2003).

[3]. Zhang, J., Wu, X., "Predictive functional control simulation of boiler combustion control system", In:Proceedings of 2nd International Conference on Mechanic Automation and Control Engineering, Lu, X.P., Wang, Z.H., eds., IEEE, Hohhot, China, 529-532 (2011).

[4]. Chen, H.G., Xie, K.C., "Combustion and NOX emission behavior of Chinese coals", Chin. J. Chem Eng., 10 (3), 333-338 (2002).

[5]. Chen, J.H., Huang, T.C, "Applying neural networks to on-line updated PID controller for nonlinear process control", Journal of Process Control, 14 (2), 211-230 (2004).

[6]. Rong, P.X., Han, L., Li, C., "Research on the main steam pressure control system of boilers based on fuzzy PI control", In: Proceedings of 6th International Forum on Strategic Technology, Zhao, H., ed., IEEE, Harbin, China, 927-930 (2011).

[7]. Wang, S., Hua, D.P., Zhang, Z.G., Li, M., Yao, K., Wen, Z.Y., "Robust controller design for main steam pressure based on SPEA2", Bio-Inspired Computing and Applications, 6840, 176-182 (2011).

[8]. Xue, F.Z., Liu, T., Yin, J., Liang, Y., Liu, H.W., Liang, G.J., "Improved scheme and implement for boiler combustion process of thermal power plant", Control Engineering of China, 15 (2), 124-126,130(2008).

[9]. Camacho, O., Smith, C.A., "Sliding mode control: An approach to regulate nonlinear chemical processes", ISA Transactions, 39, 205- 218(2000).

[10]. Lou, G., Tan, W., Fang, F., "Control structure analysis and design for boiler-turbine units", In: 29th Chinese Control Conference, Chen, J., ed., IEEE, Beijing, China, 4958-4963 (2010).