

Study on Fuzzy Self-Adaptive PID Control System of Biomass Boiler Drum Water*

Junran Jin¹, Hengshuo Huang², Junman Sun¹, Yongchao Pang¹

¹College of Electric and Information Engineering, Zhengzhou University of Light Industry, Zhengzhou, China

²Zhumadian Power Supply Company, Zhumadian, China

Email: Jinran226@163.com

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ABSTRACT

The paper discusses the features of the Biomass Boiler drum water level. Conventional PID Control System can not reach a satisfaction result in nonlinearity and time different from Biomass Boiler Drum Water Control System. In this study, a kind of fuzzy self-adaptive PID controller is described and this controller is used in biomass boiler's drum water level control system. Using the simulink tool of MATLAB simulation software to simulate the fuzzy adaptive PID and conventional PID control system, the result of the comparison shows that the fuzzy self-adaptive PID has the strong anti-jamming, flexibility and adaptability as well as the higher control precision in Biomass Boiler Drum Water.

Keywords: Biomass Boiler; Fuzzy Adaptive PID; Fuzzy Control

1. Introduction

The biomass energy is the energy that can be transformed solar energy into chemical energy and stored in the organisms internal with the help of the green plant photosynthesis directly or indirectly. Modern biomass is seen as one of the most promising renewable energy sources in the near future. Using biomass to generate energy carries like heat, electricity and gaseous and liquid fuels can contribute significantly to the reduction of greenhouse gas emissions, as shown in many studies and project in most scenarios about potential development of energy and economic systems [1]. Biomass boiler can improve the utilization of biomass for centralized large-scale use of biomass energy, adopting advanced combustion technology to transform the biomass into the boiler fuel [2]. Development of biomass boiler technology can save coal and other fossil fuels which will help alleviate the energy crisis and meet the national energy saving policy.

In the biomass boiler combustion system, the boiler drum water level is an important parameter and it is a sign to measure whether boiler steaming-water system is balance. Maintaining the boiler drum water level in the specified range is a necessary condition and one of the important indexes for the boiler safe operation. If the water level is too low, the water of bubbles lessens at the same time the load largeness. The results are the vaporization speed is very fast and the change rate of water

volume is also high. The boiler will explode if it isn't controlled in time [3]. If the water level is too high, it will influence the steam water separation. Then steam with water makes superheated fouling and destroys it. If steam with water is the energy of the turbine, superheated steam drops dramatically so that turbine blades are damaged and it causes the problems of safety and economy. So it is not allowed that the water level is too low or too high. Because many confounding factors, such as biomass fuels' humidity, density, type, as well as the change of boiler load are uncertain, time-varying, non-linear, biomass boiler combustion system is actually a fluctuation complex system, showing strong coupling, nonlinear, large inertia, time variation parameters and uncertainties. And thus it is very difficult to establish a precise mathematical model. Because the traditional PID control can not meet the control precision and the corresponding speed requirements, fuzzy adaptive PID control theory is a new theory combining traditional PID control and fuzzy logic, which does not require the exact mathematical model of controlled object and adapt to the fast, small overshoot, and the short transition. This control method is suitable for biomass boiler drum water level control system [4].

2. The Design of Fuzzy Controller

2.1. The Control Difficulties of Biomass Boiler Drum Water Level

Biomass boiler drum water level is important monitoring parameters in the boiler operation. It indirectly reflects

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the equilibrium relation between boiler steam load and water inflow. Keeping the right level of the steam pocket is the essential condition to ensure the safety of boiler and steam turbine. Because of the change of the steam load and the feeding water pressure, there is “false water level” phenomenon appearing in the boiler. In the operation, when steam load increases, evaporation is greater than the feed water. Water level rises rapidly. It caused by steam volume in the steam water mixture increasing rapidly. This phenomenon called “false liquid level”. When the steam load increases sharply, the water level drops after rising for a while. When the steam load decreases sharply, the water level rises after dropping for a while. “False liquid level” phenomenon appears when this controlled variable is disturbance. If the feed water using single loop system which viewed water level as controlled variable, the adjuster will opposite the direction of the water flow and the direction of the change in load [5]. Consequently, it enlarges the imbalance between input flow and output flow.

Conventional PID control can't solve the “false liquid level” phenomenon well. However, if the fuzzy control arithmetic is put into the “false liquid level”, the water level of steam boiler can be controlled well.

2.2. The Composition of Fuzzy Self-Adjusting PID Controller

Fuzzy self-adjusting PID controller is composed of adjustable PID controller and fuzzy controller. The core is fuzzy controller. It contains fuzzification, repository, fuzzy inference, defuzzification, and input/output quantification and so on. Fuzzy logic is a rule which can map a space-input to another space-output. In engineering application, fuzzy logic has the following characters: 1) Fuzzy logic is flexible; 2) Fuzzy logic is based on natural language, and the requirement for intensive reading of data is not very high; 3) Fuzzy logic can take full advantage of expert information; 4) Fuzzy logic is easy to combine with traditional control technique [6].

Fuzzy self-adjusting PID controller takes E (the error between feedback value and desired value of controlled station) and E_c (error rate) as input. Using fuzzy reasoning method it adjusts the PID parameters (K_p , K_i , K_d) which can meet the requirements of E and E_c for PID parameter self-setting in different time. Change the PID parameters on line by using the fuzzy rules; these functions form the self-setting fuzzy PID controller. Its control system architecture is shown in **Figure 1**.

2.3. Membership Function of Linguistic Variable

According to the precision and control requirements, it is appropriate that 7 levels are usually selected. The range of fuzzy analects for input variable E , E_c is usually $[-3, 3]$, which which is shown in **Figure 2**; the range of fuzzy

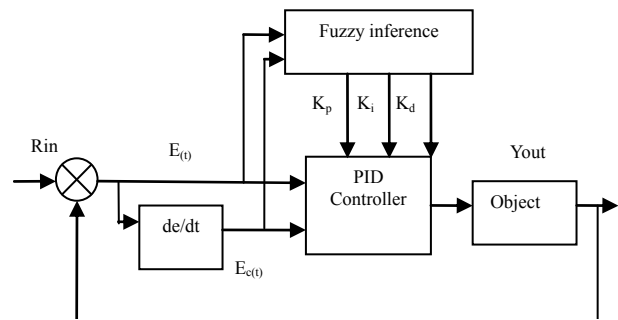


Figure 1. The structure of fuzzy self-adjusting PID controller.

analects for the output of K_p is $[-0.3, 0.3]$ and the range of fuzzy analects for the output of K_d is $[-0.3, 0.3]$, which are shown in **Figure 3**; the range of fuzzy analects for the output of K_i is $[-0.06, 0.06]$, which is shown in **Figure 4**. The analects linguistic values of input/output linguistic variable are PB, PM, PS, ZO, NS, NM, NB. The following figures are the membership function of linguistic variables' definition.

2.4. The Control Rules of Fuzzy Controller

The three parameters of PID arithmetic will influence stability, response speed, overshoot and steady precision of the system [7]. In the process operation system, the auto modification rules for E (different error), E_c (error rate), K_p , K_i and K_d are following items.

1) When E is relatively big, we should take the bigger K_p and the smaller K_d to make sure that the system has a good tracking performance. We should also strictly take an integral action to avoid the system has a larger overshoot. Usually take $K_i = 0$;

2) When E and E_c is quite suitable, we should make the K_p smaller to make sure the system has a smaller overshoot. On this occasion, we should take the suitable K_i while K_d has important influence on system;

3) When E is very small, we should take the bigger K_p and the bigger K_i to make sure that the system has a stable performance. We should also take a suitable K_d which is based on E_c to avoid the system oscillation appeared in set value. When E_c is small, take a bigger K_d ; When E_c is big, take a smaller K_d . We make some control-rule figures in the following tables according to the setting principle and the simulation test.

It needs you to transform the output energy of fuzzy controller into accurate quantity after the design of control rules. Then the data can be sent to control actuator. The design realized the organization of fuzzy quantity by using of method of weighted mean [8]. The **Tables 1-3** are showing the fuzzy control rules of K_p . In the online operation, it works out the deviation and the deviation rate in current time by constantly testing the output data of the system. Then fuzzifier them and get E , E_c , you can get

Table 1. K_p fuzzy control rules.

E_c	E						
	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

Table 2. K_i fuzzy control rules.

E_c	E						
	NB	NM	NS	ZO	PS	PM	PB
NB	NB	NB	NM	NM	NS	ZO	ZO
NM	NB	NB	NM	NS	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

Table 3. K_d fuzzy control rules.

E_c	E						
	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	NM	NM	NS	NS	ZO
ZO	ZO	NS	NS	NS	NS	NS	ZO
PS	ZO	ZO	ZO	ZO	ZO	ZO	ZO
PM	PB	NS	PS	PS	PS	PS	PB
PB	PB	PM	PM	PS	PS	PS	PB

the adjusted quantity of the three parameters through control rules. All these steps are the adjustments to the controller parameters.

3. Simulation Research

The model is constructed in the environment of Matlab/Simulink, which is composed of fuzzy controller, PID control module, controlled member and input/output,

using Simulink, Simulink extras, fuzzy logic and toolbox.

3.1. The Editor of Fuzzy Controller

In MATLAB, a new FIS file is made by the FIS editor to confirm the structure and membership of fuzzy controller. As shown in **Figure 5**.

Input the membership functions and fuzzy rule of E,

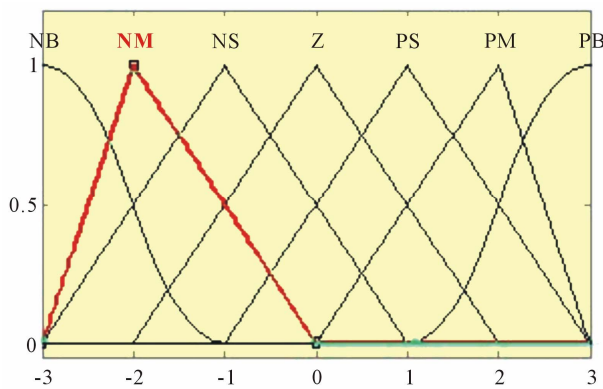


Figure 2. E, E_c membership function curve.

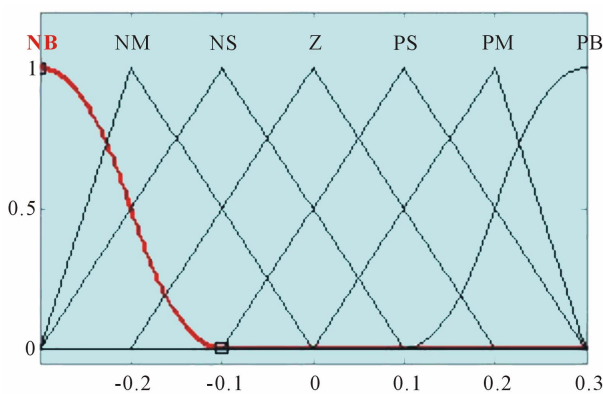


Figure 3. K_p, K_d membership function curve.

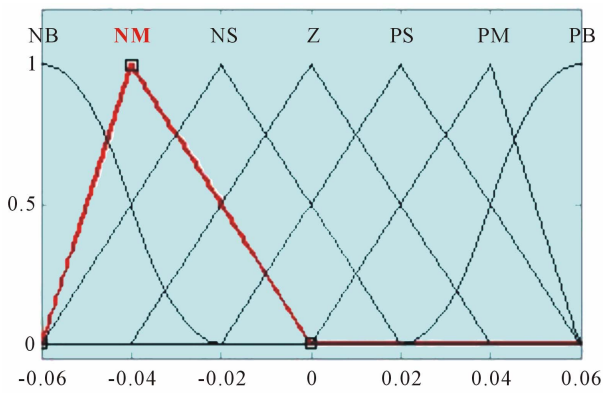


Figure 4. K_i membership function curve.

E_c, K_p, K_i, K_d in turns. And “and method” is regarded as min, “or method” as max, “implication” as min, “aggregation” as max and “defuzzification” as centroid. The file is saved and loaded into workspace when you want to simulate the module.

3.2. The Simulation of Fuzzy Self-Adjusting PID Controller (Figure 6)

Select a boiler drum as controlled object. And the transfer function of feeding water flow and water level is

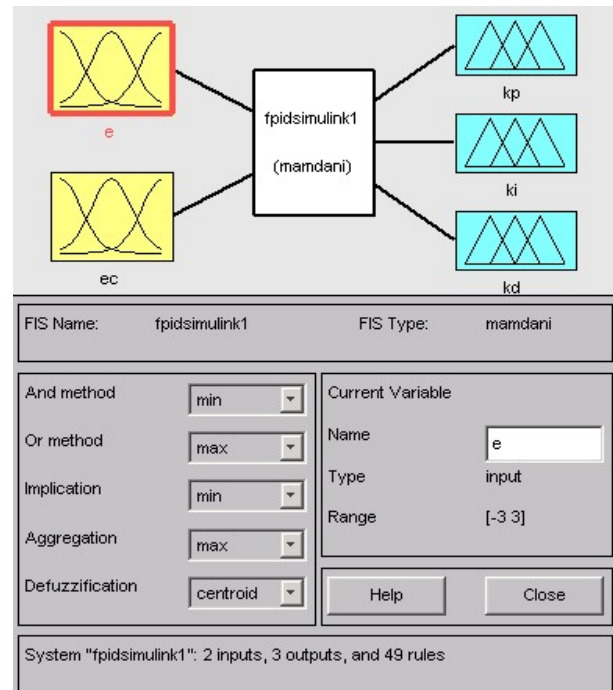


Figure 5. FIS editor window.

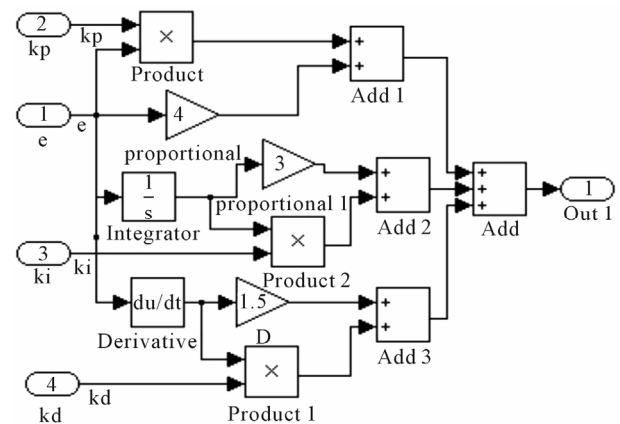


Figure 6. PID control rblock diagram.

$G(s) = \frac{10}{2s^2 + 3s + 1}$, justification factor $K_e = 0.9$, $K_{ec} = 0.1$. Defuzzification factor $K_1 = 3$, $K_2 = 1.2$, $K_3 = 0.01$, PID initial value $K_p = 4$, $K_i = 3$, $K_d = 1.5$.

4. Analysis of Simulation Results

In this section, the step response simulations by using fuzzy PID control and PID control respectively. Furthermore, authors make some comparisons between them. The simulation results are shown by Figures 6-9.

It can be seen that the fuzzy adaptive PID controller makes the speed of response much quicker, the overshoot much smaller, and the oscillation time much shorter such that the states soon reach the level of stability than that of

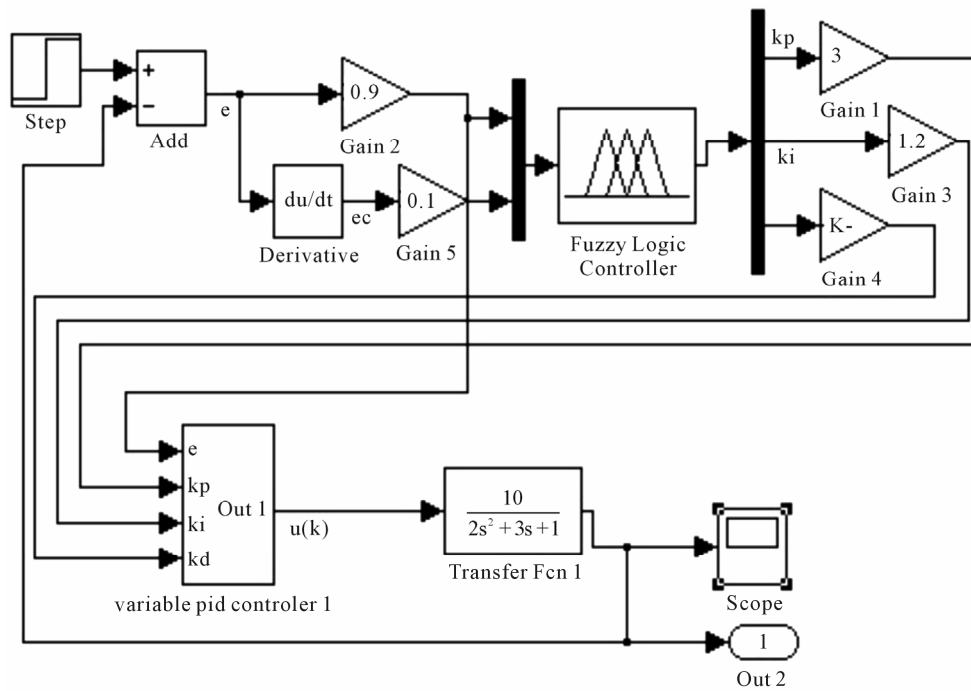


Figure 7. Fuzzy adaptive PID controller rblock diagram.

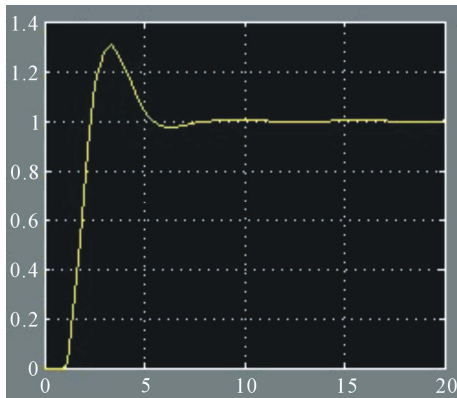


Figure 8. The simulation wave forms by using the PID control.

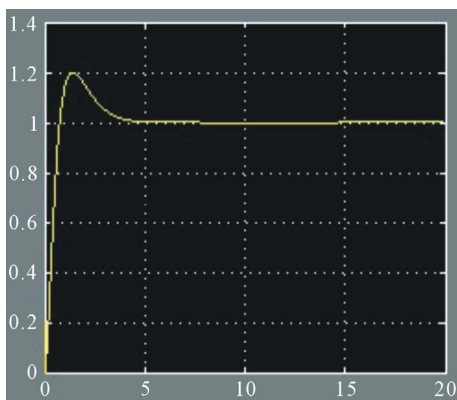


Figure 9. The simulation wave forms by using the fuzzy adaptive PID control.

the PID controller. In a word, the fuzzy adaptive PID controller shows good dynamic and static performance indicators. The fuzzy adaptive PID control algorithm merges the advantages of the PID control and the fuzzy control, and it provides a good control method for the complex systems and the systems with higher demand dynamic process.

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