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Research Article

A Study of Boiler Water Level System with Fuzzy Control Method

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ABSTRACT

In this paper, the performance characteristics of the boiler water level system are analyzed, and a fuzzy control method is used to control it based on the three-stroke water supply system. This fuzzy control method is to reason out the appropriate fuzzy control rules, design fuzzy controller, and applied to the control system, so that the system for self-adjustment of PID parameters, constitute a fuzzy PID control system. On this basis, this paper analyzes the performance, advantages and characteristics of two control systems: the traditional PID control system and the fuzzy PID control system, and simulates the parameters of the input variables for comparison and analysis.

1. Introduction

Boilers are playing a very important role in factory production. The main task of boiler production is to convert the chemical energy of coal or natural gas into the thermal energy of steam and eventually into other energy sources such as electricity. It is a large-area capacity facility used in industrial production processes. Therefore, boiler safety is an issue of great concern to us.

Boilers are often disturbed by external disturbances during the working process. It would be unrealistic to rely on the operator to keep it running accurately in the plant for long periods of time. 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 [1].

In the boiler drum water level fuzzy control system, fuzzy control method is the most dominant control method, which based on fuzzy logic theory, fuzzy set theory and fuzzy language variables.

The fuzzy PID boiler water level control system is investigated and analyzed in terms of model and characteristics. The rules used by the fuzzy logical controller will be written using the Fuzzy Logic Toolbox [2] in MATLAB.

The fuzzy control is not necessarily an accurate mathematical analysis of the controlled object, but rather a combination of fuzzy control algorithms and PID control to control non-linearity, make the boiler level system stable and robust.

2. System Control Principle

Generally speaking, the larger the boiler drum capacity, the larger the volume of steam mixture and steam in the drum. Sufficient space is required for separation and circulation, and the moisture content of the generated steam is much more stringent. In turn, the water level of the cartridge is also very strict.

In a double pulse control system with level signal and steam signal, the water supply valve does not automatically adjust the amount of water supply in a timely manner, which will cause a delay, and thus the water level in the steam drum will also be deviated. The

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tri-pulse control system introduces the control amount of the water supply signal based on the level and steam signals of the double-pulse control system.

2.1. *boiler water level system structure*

Boiler drum water level control system consists of Economizer, Drum Boiler, Down tube, Superheater, Lifter tube, Water Supply and so on.

The workflow of the boiler is as follows:

First, the boiler obtains water through a water supply control valve. Second, the water passes through an economizer where it absorbs heat from the burning fuel, regulates it to the amount of water supply, dynamically equilibrates the steam mixture and liquid water in the steam package by regulating the water supply. Third, the water passes through the water cooling wall around the furnace in the top connection box, and finally returns to the steam package [3]. Boiler drum water level control system is shown in the Fig.1.

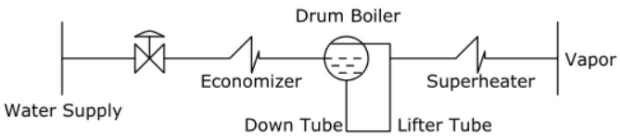

Fig.1. Boiler drum water level control system

2.2. *principles of PID control*

Start with the classical PID control, which consists of proportional, integral, and differential components. The proportional part of this is to maintain system stability. The larger the proportionality factor, the faster the control action of the system and the higher the accuracy of the control. However, if the proportionality factor is too large, oscillations can occur. Therefore, the scale factor K should be appropriate to achieve the effect of small transition time, small static difference, and high stability.

The function of the integral part is to eliminate systematic deviations and stabilize the control system in the process of regulation. The larger the integration time, the weaker the system's ability to eliminate deviations and the longer the transition time. The smaller the integration time, the greater the ability to eliminate deviations that may cause the system to oscillate. The role of the differentiation is to improve the instantaneous response of the system. The larger the differentiation time, the stronger the differentiation effect. Classical PID Control Schematic Block Diagram is shown in Fig.2.

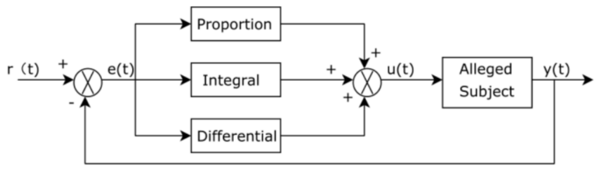

Fig.2. Classical PID Control Schematic Block Diagram

The control rule is

$$U(t)=K_P\left[e(t)+\frac{1}{T_i}\int_0^t e(t)\,dt+T_D\frac{d_{e(t)}}{d_t}\right] \quad (1)$$

When selecting a PID controller, choose a simpler and more accurate incremental PID controller.

$$\Delta U(k)=u(k)-u(k-1) \quad (2)$$

Only the first three deviations are needed to calculate ΔU(k), and the incremental PID control algorithm is now widely used.

2.3. *cascade control systems*

The cascade control system consists of two parts: inner closed-loop and outer closed-loop. The execution of the control sequence of the system is the outer ring first, followed by the inner ring. Cascade Control Systems is shown in Fig.3.

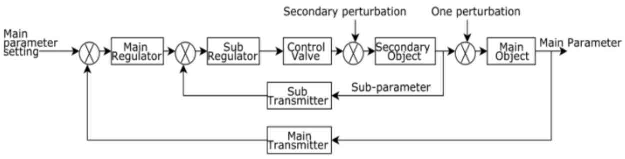

Fig.3. Cascade Control Systems

3. Design of Fuzzy Controller

The following introduces the basic structure of the fuzzy controller, and the fuzzy controller designed in this paper.

3.1. *the basic structure*

It consists of four parts: Knowledge Base, Fuzzy Reasoning, Fuzzification of Inputs, and Accuracy of Outputs.

First, the input quantity is fuzzified and reasoned about by the knowledge base, and finally decoupling the output quantity to be precise. Basic structure of the fuzzy controller is shown in Fig.4.

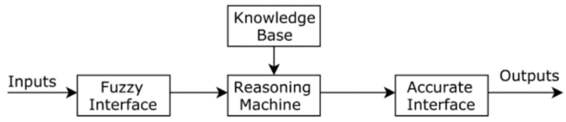

Fig.4. Basic structure of the fuzzy controller

3.2. *design process for fuzzy controller*

There are the following steps.

Define input and output variables. Controller has two inputs and three outputs. The two input variables are the water level deviation and the deviation variation, The three output variables are K_P、K_I、K_D.

Fuzzing of Inputs. The set of input and output words is denoted by {NB,NM,NS,ZO,PS,PM,PB} and the subordinate function is chosen to be an isosceles triangle. Isosceles triangle affiliation function image is shown in Fig.5.

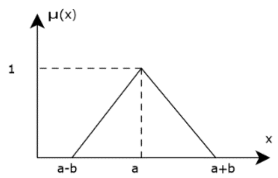

Fig.5. Isosceles Triangle Affiliation Function Image

Define fuzzy rules. Make separate tables of the three output variables and analyze how they change on their own as E and Ec change. The 49 control rules are deduced from practical experience. The Kp is shown in the Table 1.

Table 1. Kp Fuzzy Rules Table

e\ec	NB	NM	NS	ZO	PS	PM	PB
NB	PB	PB	PM	PM	PS	PS	0
NM	PB	PB	PM	PM	PS	0	0
NS	PM	PM	PM	PS	0	NS	NM
ZO	PM	PS	PS	0	NS	NM	NM
PS	PS	PS	0	NS	NS	NM	NM
PM	0	0	NS	NM	NM	NM	NB
PB	0	NS	NS	NM	NM	NB	NB

The rule table reasoning for $K_I$and K_D is the same as above.

Precise variables. Use of the weighted average method (center of gravity method) to accurately the output variables of the control system.

4. Control System Modeling and Simulation

Design of automatic adjustment of steam packet level according to boiler water level dynamics.

4.1. *classical PID control modeling*

From empirical data, under unit step perturbation of feedwater flow rate, floating velocity of boiler water level V=0.05 mm/s.

The time constant T2 = 15s, so the transfer function is determined as G(W) = 0.05/(15S^2+S). Under steam flow perturbation, the amplification factor K2 = 5, T2 = 15s, yielding the transmission G(D) = -0.05/S+S/(15S+1).

The boiler water level model is built using the SIMULINK toolbox in the MATLAB environment, and the three parameters Kp=10, Ki=0.0045, and Kd=0 are obtained by the improvised test method [4]. Classical PID control model is shown in Fig.6.

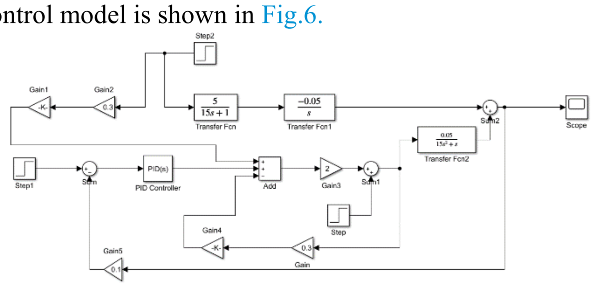

Fig.6. Classical PID control model

4.2. *fuzzy PID control modeling*

To build a fuzzy PID control model, a designed fuzzy controller needs to be added to the traditional PID model. Fuzzy PID control model is shown in Fig.7.

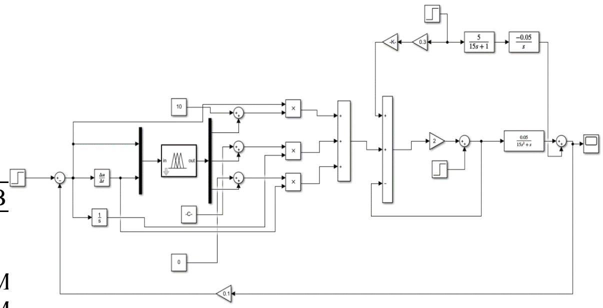

Fig.7. Fuzzy PID control model

4.3. *simulation results analysis*

Simulation graphics with only level perturbation

Simulation diagrams with only level disturbance is shown in Fig.8. The left figure shows the simulation results of the classical PID control model and the right figure shows the simulation results of the fuzzy PID control model.

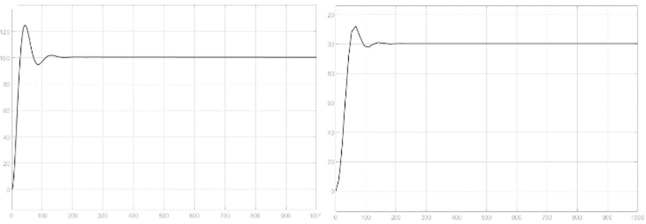

Fig.8. Simulation diagrams with only level disturbance

Add steam disturbance at 500s while having level disturbance. Simulation diagrams for liquid level disturbance and vapor disturbance is shown in Fig.9.

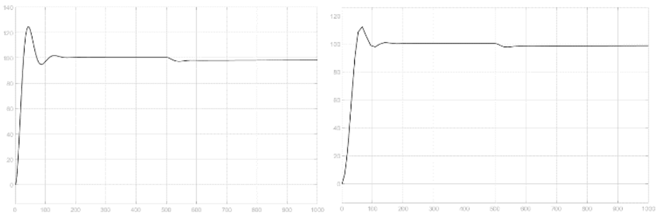

Fig.9. Simulation diagrams for liquid level disturbance and vapor disturbance

From the two graphs, the fuzzy PID control system (right) has better overshoot and setting time than the classical PID control system (left). When multiple perturbations are added, the fuzzy PID control system is more stable.

5.Conclusion

By analyzing the dynamic and static characteristics of the automatic drum water level control system, the paper constructed a conventional PID simulation model and a fuzzy PID simulation model. And the simulation results of both are compared and analyzed, it can be concluded that the fuzzy PID control system has a small amount of overshoot, short oscillation period and short setting time.

Fuzzy PID control system has greater flexibility and robustness, and better fault tolerance. Verified the good performance of boiler water level system under fuzzy control method.

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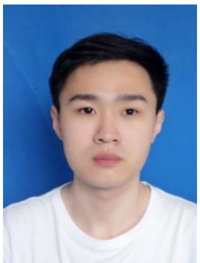

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