Design of Biomass Boiler Intelligent Heating System Using Fuzzy PID

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Abstract: Fuzzy PID control scheme is proposed for the heating system of biomass hot water boiler characterized by nonlinearity, large inertia, uncertainty and time delay. It is used in the heating system due to high control accuracy and robustness. In this paper, fuzzy control rules are established to analyze the characteristics of indoor temperature rise. Fuzzy inference method is adopted to realize on-line tuning of PID parameters. In addition, the hardware and software design of Fuzzy PID controller are introduced in this paper. Fuzzy PID control is obviously better than the conventional Proportional-Integral-Derivative (PID) control shown in the experimental results. The indoor temperature is maintained at the comfortable human performance indicators by parameters self-tuning Fuzzy PID control, which is an ideal energy saving control program.

1 INTRODUCTION

There are several reasons for using biomass energy. China is a big agricultural country with large crop straw production, wide distribution and many kinds of crops (Wang, 2008). Therefore, it is a great significance to make the crops into biomass fuel. Biomass is a clean and renewable energy, and the development and application of biomass energy is a broad prospect. Biomass boilers are used in district heating and power generation in developed countries such as Denmark, the United States and Italy (Dalólio, 2017). Biomass boilers instead of coal-fired boilers in many aspects, for example, decentralized heating, catering, bathing, swimming pool and other facilities, which has more practical significance (Herbert, 2016).

The heating process of hot water boiler has always been the focus of research in the field of process control (Cai, 2014). In recent years, domestic and foreign scholars have carried out research on temperature control system based on fuzzy control, Fuzzy PID control and PID control (Duan, 2004). Shen Guomin (Lu, 2010) put forward the hot water boiler heating control, and the water temperature is controlled according to the outdoor temperature changes, which did not take into account the specific circumstances of indoor temperature changes. Aiming at to solve the shortcomings of above methods, biomass boiler intelligent heating system based on Fuzzy PID control is proposed in this paper, so that the indoor temperature is faster and more stable to achieve the target temperature, to achieve the energy saving purpose of biomass boiler intelligent heating system (Neath, 2014; Sharma, 2014).

2 FUZZY PID CONTROL ALGORITHM PRINCIPLE

2.1 Fuzzy Control Theory

Fuzzy control has gained a wide acceptance, due to make control decisions not depend on the model of the object. The performance of fuzzy logic controllers is largely determined by the fuzzy rules, reasoning machines, and fuzzy decision making methods (Sahu, 2015; Chen, 2014; Duan, 2013; Sahu, 2014; Karasakal, 2013; Wu, 2003). It discusses definite nature, fuzzy and imprecise information system control in the real world. The basic structure of fuzzy controller is as below.

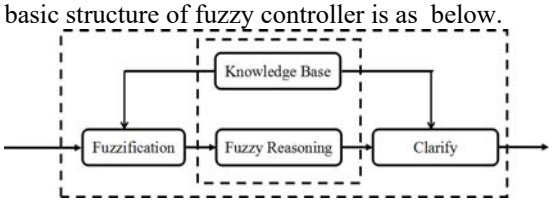

Figure 1: Basic structure of fuzzy control

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Two-input and one-output fuzzy controller is more common in practice, and also commonly referred to as two-dimensional fuzzy controller. From the theoretical analysis, the dimension of the fuzzy controller is higher, the better its control effect (Guo, 2002). The difficulty of the algorithm will be greatly improved, while the deviation e and its rate of change ec are taken as input. The overall performance of the fuzzy dimension controller is very good and the difficulty of realization is moderate, so it is applied more extensively.

2.2 Research on Fuzzy PID Algorithm

The fuzzy control system block diagram of adaptive fuzzy PID controller designed in this paper is shown in the following figure, in which the fuzzy controller is established in the dashed box (LongMan, 2000). The fuzzy controller module is two input and three output, for example, the deviation e and its rate of change ec as input, based on a series of fuzzy rules and fuzzy decision making results, which ΔK_p, ΔK_i and ΔK_d of real-time output is adjusted by fuzzy controller. Furthermore, the adjustment amount and the initial value of the PID parameter due to achieve online parameters, so that it is maintained in the best working point (Zhang, 2006). Adaptive fuzzy PID control block diagram is as below.

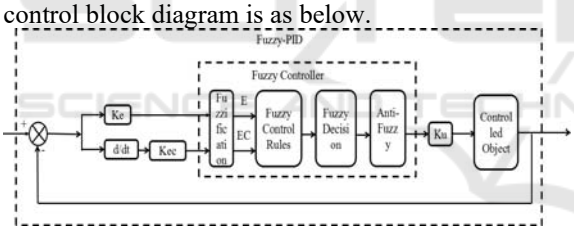

Figure 2: Block diagram of Fuzzy PID control

PID controller of indoor temperature is adjusted by linear combination, its discrete general formula (Pinsker, 2016) is as below:

$$u(t) = K_p(e(t) + \frac{T}{T_i}\sum_{t=0}^{t-1} e(t) + \frac{T_D}{T}(e(t) - e(t-1))) \quad (1)$$

The parameter e and the rate of change ec are given by the following equation, which the predicted value (Azar, 2015).

$$\begin{aligned} K'_p &= K_p + \Delta K_p \\ K'_i &= K_i + \Delta K_i \\ K'_d &= K_d + \Delta K_d \end{aligned} \quad (2)$$

3 INTELLIGENT HEATING SYSTEM

According to the literature, the energy saving ratio of the envelope and the heating system is about 1:1, while it is not obvious to the effect in the development and application of the energy saving envelope. Therefore, it has great potential to research on heating system. The design of biomass hot water boiler intelligent heating system consists of biomass hot water boiler CLHS0.035-85/65-M and its ancillary equipment (such as draft fan, feeder, water pump, ignition controller, LCD Display, keys, temperature sensors, pressure sensors, water level measuring devices, flow meters, etc.), and heating systems (such as heat exchangers, radiators, water tanks, etc.)

The proposed special optimization control algorithm in this paper solves the system optimization and energy saving operation problem of the biomass water heating boiler system. Furthermore, static and dynamic data combined with analytical methods is used to ensure the biomass boiler heating system operated safely,even in the best state, real-time dynamic control. The intelligent control system composed is as below:

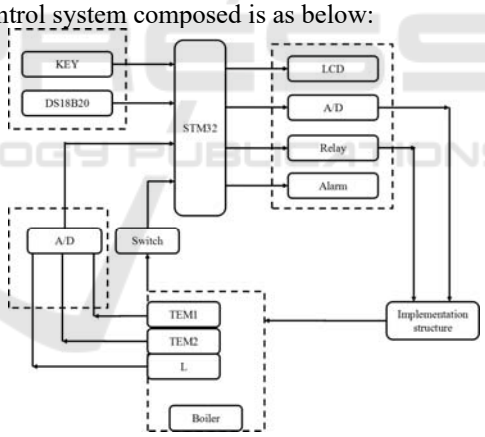

Figure 3: Structure of the control system for small heating equipment

In this paper, intelligent heating control system based on embedded design,which consists of ARM, DS18B20, the sensor(such as temperature, flow and water level), and A/D is used to converted continuous signal into digital signal which is sent to the controller via I/O. And then get the operation instructions of the water supply system, the feeding system, the ignition system, the induced draft dust removal system, the air supply system, the flame out and the fire protection system. Instructions are sent out through I/O output, to control the relay

closed and disconnected, the actuator to run and stop; At the same time, the operating status of the various actuators, such as temperature, liquid level and other parameters are shown on LCD display. Physical map is as below.

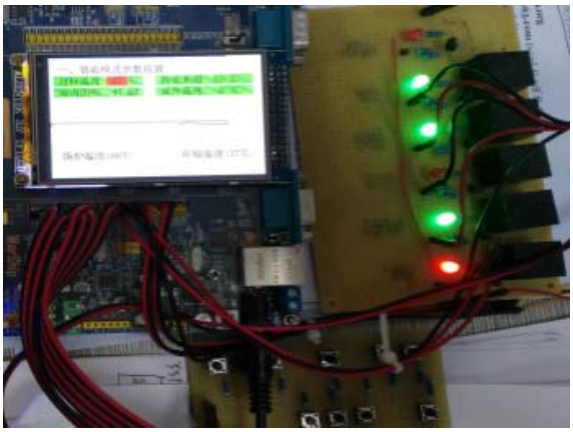

Figure 4: Physical map of Controller

In this paper, indoor temperature is collected, and the deviation e and the rate of change ec are calculated. Fuzzy-PID control algorithm is adopted, and k_p=0.6, k_i=0.1 and k_d=0.1. Intelligent heating system algorithm flow chart is as below.

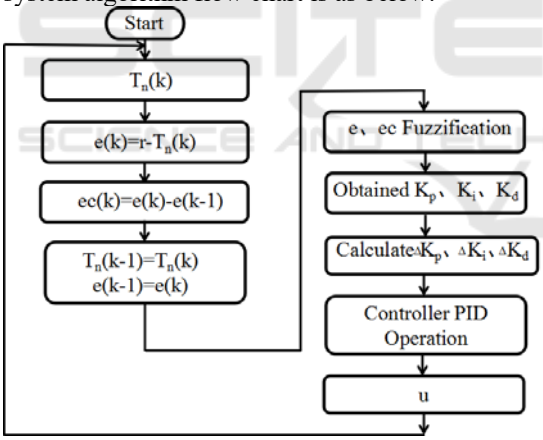

Figure 5: Flow chart of ntelligent heating system algorithm

When the system in the steady state, the amplitude interference signal observed is added to the two systems,so that the anti-interference performance is observed. It can be seen from the simulation results that the response of the loop where the adaptive fuzzy PID controller is small and reaches a steady state fast again, which has a strong anti-interference performance compared with the conventional PID controller.

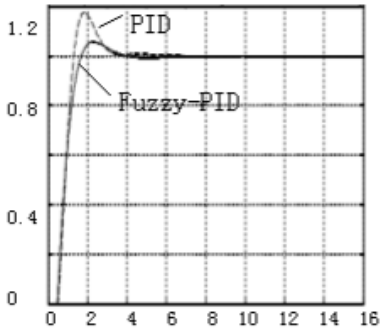

Figure 6: Curve of unit step response

4 RESULTS AND ANALYSIS

The room temperature variation trend is recorded in this experiment, and the experimental data of intelligent controller compared to conventional controller. A temperature sensor (DS18B20) was installed all around the laboratory. The four temperature sensors were placed 0.5m away from the wall, and the measured room temperature was sent to the controller. The indoor heating target temperature is 23℃in the experiment, then the heating room temperature contrast curve is as below.

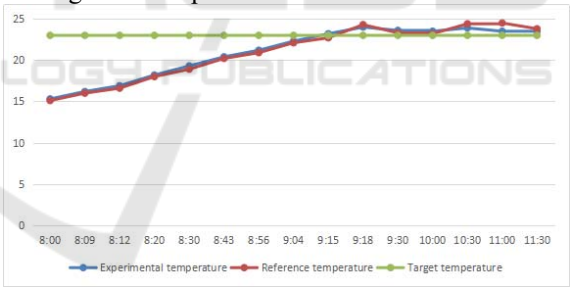

Figure 7: Curve of room temperature comparison

5 CONCLUSIONS

According to the characteristics of the heating system, the intelligent heating system of biomass hot water boiler based on fuzzy PID controller is developed through the integrated application of intelligent control technology such as embedded technology, fuzzy control, PID controller and cascade control, etc. In this experiment, the fuzzy PID controller of heating system was compared without controller measurement. The results are

shown that the intelligent control system has the ability to respond to the dynamic performance fast and improve the steady-state accuracy. In order to solve the complex problem of nonlinear and large time-delay, a new control idea is provided .

In order to be realized accurate monitoring and control of biomass boiler heating, the hardware and software of the system are tested and perfected for a long time and the performance of the whole system is improved. According to the existing research results, it is planned to do further research on the function expansion of heating system of biomass hot water boiler and intelligent adaptive heating control.

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