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Parameter Adjustment of the Boiler Level Controller in the Process Control System of a Thermal Power Plant

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ABSTRACT:In a thermal power plant, steam carrying heat is directed to the turbine to rotate the generator. Theboiler of thethermal power plant is required to maintain its constant water level to produce steam at high temperature and high pressure.Notably, the boiler is the largest and most complex equipment. This paper is to design the controller of the boiler level control system and then adjustits parameters to meet the system requirements.Numerical and experimental results prove the effectiveness of the proposed controller.

KEYWORDS: thermal power plant,boiler, level controller, process control.

I. INTRODUCTION

The principle of electricity production of a thermal power plant is to convert the heat energy into mechanical energy to rotate the turbine, and convert the mechanical energy of the turbine into electrical energy in the electric generator [1-3]. Heat energy generated by burning fuels in the boiler is sent to the turbine through a thermal conductor. It is steam.Steam is only a medium to transfer heat energy, but steam still has to ensure quality (such as sufficient pressure, enough dryness) before entering the turbine to generate torque. The more heat is supplied, the greater the electrical energy is generated and vice versa. The voltage generated at the generator terminals will be passed through the substation system and upgraded to the appropriate voltage level before connecting to the national power grid [4-5].

The process of energy conversion,the chemical energy contained in fuel is convertedinto heat by the fuel combustion. Saturated steam is the heat transfer medium from the boiler to the turbine. At the turbine, thermal energy is converted into the mechanical energy, and then mechanical energy is converted into the electrical energy. The energy conversion process can be shown in Figure 1.

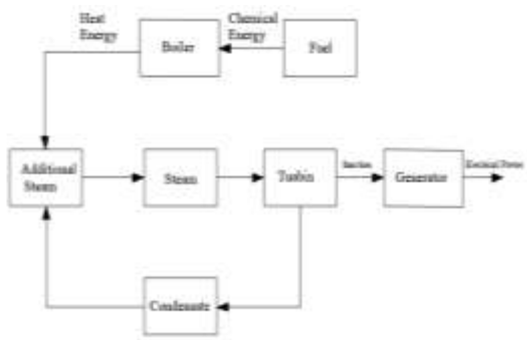

Figure 1: Energy conversion process

This study willmainly focus on the boiler element.A boiler is a system with multiple inputs and multiple outputs.The boiler input includes fuel, wind, and feed water. The boiler output consists of saturated steam released from the boiler, wastewater, smoke and slag from combustion. These inputs and outputs are closely related.With each request to change the output power of the generator, it is necessary to control the input fuel, the components of supply water,windflow, and so on. The boiler control structure is illustrated in Figure 2.

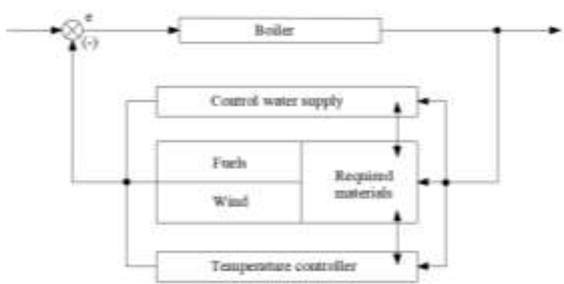

Figure 2: Boiler control structure

On the basis of the above general knowledge, thispresent article studies on controlling the boiler water level of a thermal power plant.To

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meet technological requirements, design and adjustment of controller parameters are described.

II. MATHEMATICALMODELINGOF BOILER LEVEL CONTROL SYSTEM

The process control system of a thermal power plant includes devices such as controllers, level sensors, flow sensors, motors, valves, etc. This system has many inputs and many outputs, where the input and output are closely related. For the purpose of controlling and stabilizing the boiler level, the paper introduces a control system consisting of two control loops, in which the inner flow control loop (fast acting) and the outer level control loop (slower impact). Therefore, the structure diagram of the boiler level control system is shown in Figure 3.

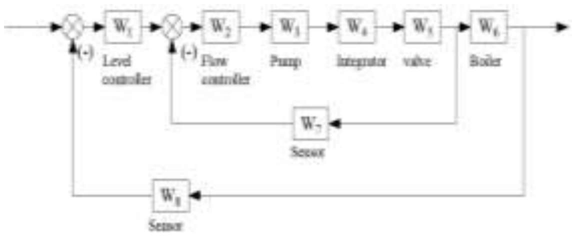

Figure 3: Block diagram of level control system

The transfer function of the elements in the structure diagram of a level control system is written as follows:

The electric drive system of thewater supply regulator is a DC motor that rotates the valve with a capacity of 1KW, rated voltage of 220V. Input is voltage, output is angular velocity.

The transfer function of the drive system of the water supply regulator (pum) is expressed as follows:

$$W_3(s) = \frac{k_3}{T_1 T_2 s^2 + T_2 s + 1}$$

where k_3 is the gain of the motor (k_3=3.3); T_1 is the electromagnetic time constant from the rotor electric circuit (T_1=0.2); T_2 is the electromechanical time constant of the electric drive system(T_2=0.25).

Since the input signal of the valve is angular velocity and the output signal of the electric actuator is speed, the integral step is added. The transfer function of the integral step has the following form:

$$W_4(s) = \frac{k_4}{s}$$

where K_4 is the gain of the integral (k_4=1).

The input signal is the angular velocity, the output signal is the water flow. The relationship between the output signal and the input signal of the valve is a first-order inertial link. The transfer function has the form:

$$W_5(s) = \frac{k_5}{T_5 s + 1}$$

where k_5 is the gain of the valve (k_5=0.5); T_5 is the time delay (T_5=1).

The input signal is the water flow, the water is made into steam, the output signal is the steam flow. The relationship between the output signal and the input signal of the boiler is a first-order inertia step with hysteresis. So the transfer function of the boiler has the following form:

$$W_6(s) = \frac{k_6}{T_6 s + 1} e^{-\tau s}$$

where k_6 is the gain of the boiler (k_6 = 15); $T_6$is the time constant (T_6=80);τ is the approximate delay time (τ=6).

The input signal of the sensor is water flow, the output signal is a DC current from 0÷5 mA, so the transfer function of the water flow sensor is proportional. The transfer function of the water flow sensor is written as follows:

$$W_7(s) = k_7 = \frac{\Delta I_{max}}{\Delta Q_{max}}$$

where ΔI_{max} is the maximum output current of the sensor (ΔI_{max} =5mA); ΔQ_{max} is the maximum flow rate of the sensor(ΔQ_{max} =63 cm^3/s).

The input signal of the sensor is the water level, the output signal is the DC current from 0÷5mA. So the transfer function of the water level sensor is proportional and has the following form:

$$W_8(s) = k_8 = \frac{\Delta I_{max}}{\Delta H_{max}}$$

where ΔI_{max} is the maximum output current of the sensor (ΔI_{max} =5mA); ΔH_{max} is the maximum water level of the sensor (ΔH_{max} =630 cm).

III. DESIGN OF PID CONTROLLER FOR BOILER LEVEL CONTROL SYSTEM

According to the control structure and calculate the transfer function of the components in the boiler level control system above, we can build a control system simulation diagram on MATLAB/Simulink. Using symmetric optimization criteria to design PID controller [4-5]. Structure diagram of internal flow control loop using PID controller as shown in Figure 4 and structure diagram of external level control loop using PID controller as shown in Figure 5.

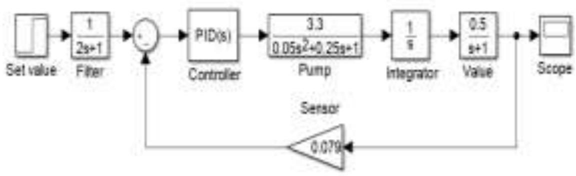

Figure 4: The flow control loop

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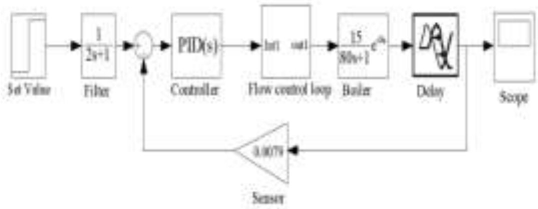

Figure 5: The lever control loop

The responseof the flow control loop as shown in Figure 6.

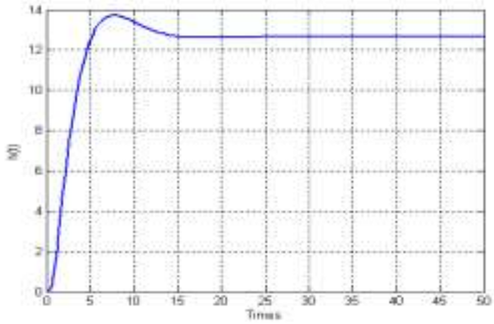

Figure 6: The responseof flow control loop with PID controller

Theresponseof the level control loop are as shown in the figure 7.

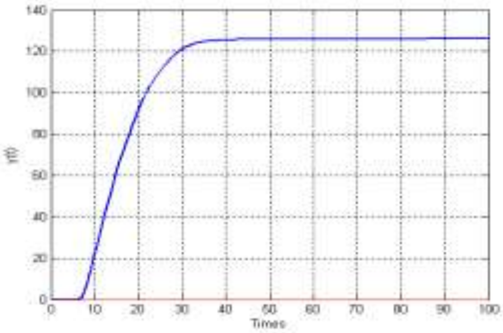

Figure 7: The responseof level control loop with PID controller

The simulation results of the control system using the PID controller show that the response of the system tracksthe desired value and is kept stable, meaning that the overshoot and settling time meet the demands.

IV. EXPERIMENTATION

Experimental research on parameter adjustment of PID controller in boiler level control system is carried out at the automation laboratory of Faculty of Electrical Engineering, Thai Nguyen University of Industrial Technology.Experimental structure of boiler level control as shown in Figures8-9. The system includes a boiler, a water pump, level sensor, flow sensor, a PID controller, a PC with the process control interface, and so on.

Figure 8: Experimental structure of boiler level control

Figure 9: The level tank in the level control model

Specifically, AC800M controller (with PID control algorithm) of ABB company is shown in Figure 10.The level controller programming interface to adjust PID controller parameters is shown in Figure 11.

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Figure 10: AC800M controller in boiler level control system

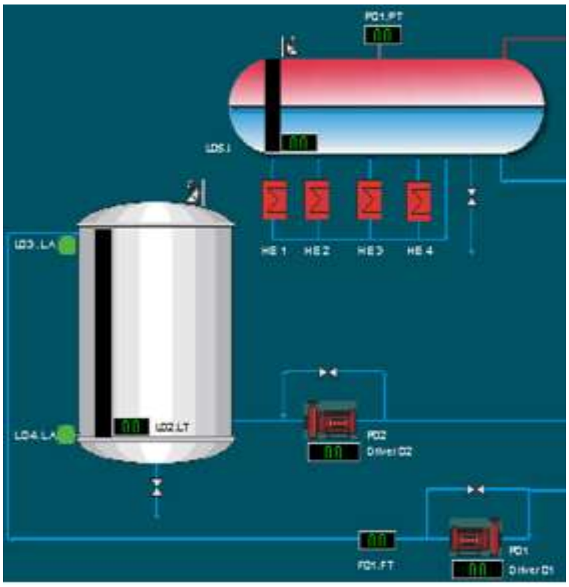

Figure 11: The level control programming interface

The parameters of the PID controller is tuned on the interface of the experimental system.of In this PID controller,K_P is the proportional gain, T_I is the integral gain, and T_D is the derivative gain.

In the flow control loop, Kp is within the range of [5, 15], T_I is within the range of [10, 20], T_D is within the range of [0.5, 1]. Meanwhile, in the level control loop, Kp is within the range of [10, 30], T_I is within the range of [10, 20], T_D is within the interval of [1, 5].

The experimental results are shown in Figure 12.After designing andtuningthe parameters of the PID controller, the experimental results meet the required quality criteria of the boiler level control system.Indeed, the left plot expresses the level control performance while the right plot describes the flow control performance. The response signal (in green) properly tracks the reference signal (in cyan).

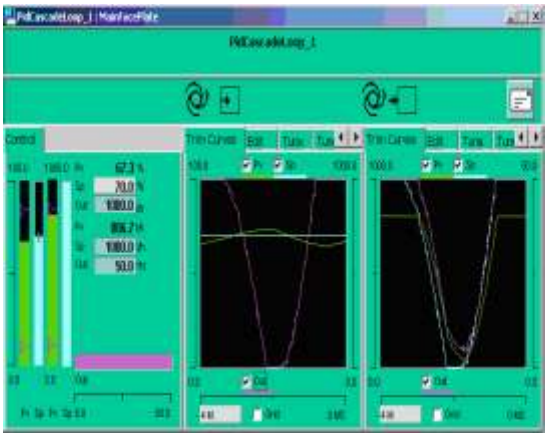

Figure 12: The experimental result with the PID controller

V. CONCLUSION

The boiler level control algorithm in the process control system of a thermal power plant has been implementedwith a PID controller. The design procedure is carried out through simulation steps on MATLAB/Simulink. In addition, an experimental system is used to verify the theory and prove the effectiveness of the PID control algorithm,the most commonly used controller in process control systems. The simulation and experimental results show that the PID controller perfectly meets the control requirements.

ACKNOWLEDGEMENTS

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