American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-7, Issue-6, pp-269-274
www.ajer.org
Research Paper Open Access

Design A Controller Applied For A Water Level Control System In A Thermal Power Plant

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ABSTRACT :*In industrial production systems, there are different technological processes that require the appearance of steam to generate torque as turbines for thermal power plants. The steam boilers of the thermal power plant are demanded to maintain a continuous water level for producing high-temperature steam and in high pressure. As a result, they might be controlled by a variety of parameters. This is a complex system with multiple control loops, so the design of the control system needs to ensure steam generation efficiency and modern control methods. The paper introduces the level control algorithm for the steam boilers of the thermal power plant and the applied controllers. The results illustrate good performances through simulations and experiments.*

KEYWORDS *-The thermal power plant, the steam boiler,cascadecontrol, PID controller, FLC controller.*

Date of Sumisión: 06-06-2018 Date of aceptante: 21-06-2018

I. INTRODUCTION

The principle of electricity production of a thermal power plant is the conversion of heat energy from the combustion of the fuels in the boiler into the turbine's rotational power; in other word, the turbine's power is converted into electrical energy in the generator. Thermal conductivity to the turbine depends on the water vapor conduction. Although steam is only a heat transfer medium, its qualityhas to be guaranteed such as sufficient pressure and dryness before entering the turbine. The electricity generation process is described in figure 1.

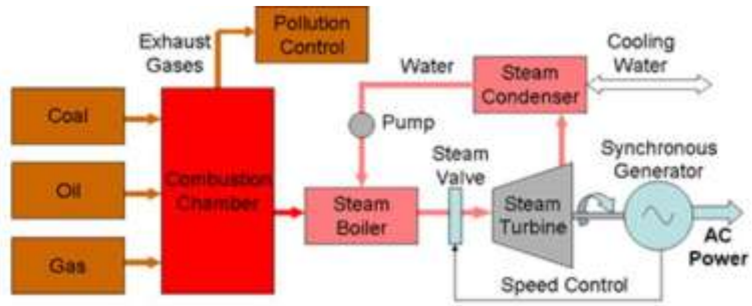

Fig. 1: The energy conversion process in the thermal power plant

The study concentrates on a control problem in the combustion chamber and the steam boiler. The combustion chamber is a multiple outputs and inputs system, in which fuel, wind and water supply are its inputs, and the output consists of saturate steam released from the steam tank, an amount of redundant water, smoke and slag from the combustion process.In this case, water is heated in a boiler until it becomes high-temperature steam. This steam is then channeled through a turbine, which has many fan-blades attached to a shaft. As the steam moves over the blades, it causes the shaft to spin. This spinning shaft is connected to the rotor of a generator, and the generator produces electricity. The steam boiler collects steam then delivers it to the turbine. Water from the steam tank is brought down to the furnace by piping. Hence, the steam boiler control system is a complex system with different control loops that monitor and control hundreds of parameters.

Based on general understanding above, the paper proposes a research of controlling the water level in the steam boiler of thermal power plants, and then continuing to design controllers meeting the required efficiency. The characteristics of the controller are illustrated by simulation and experimental results.

II. THE MATHEMATICAL MODEL OF THE WATER LEVEL CONTROLLER IN THE STEAM BOILER

The process control system of the thermal power plant including objects such as temperature sensors, pressure sensors, level sensors, flow sensors, motors, etc. As the content above, this process is a multi-input and multi-output system, in whichthe inputs and outputs are closely related to each other. For example, if the required power of the generator is changed, it will be necessary to control the changing amount of the fuels and supply water, wind. The structure of the steam boiler is described in Fig. 2 and the control principle of the system is illustrated in Fig. 3.

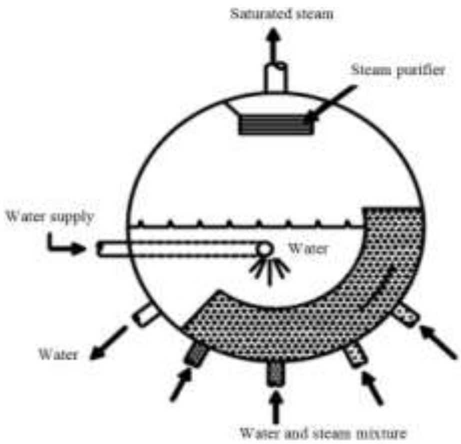

Fig. 2: The steam boiler in the thermal power plant

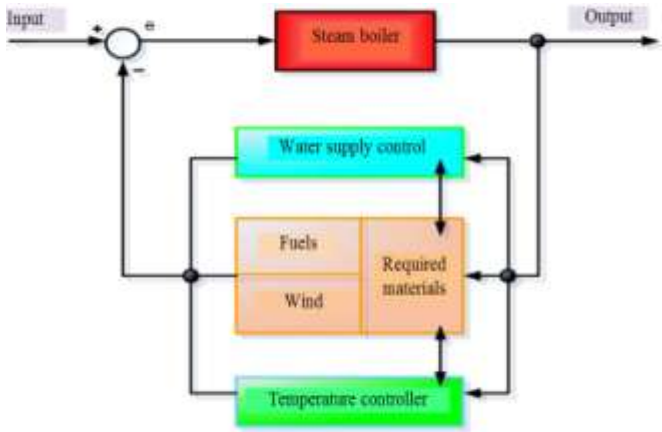

Fig. 3: The structure diagram of the steam boiler

Therefore, the schematic diagram of water level controller is formed as Fig. 4.

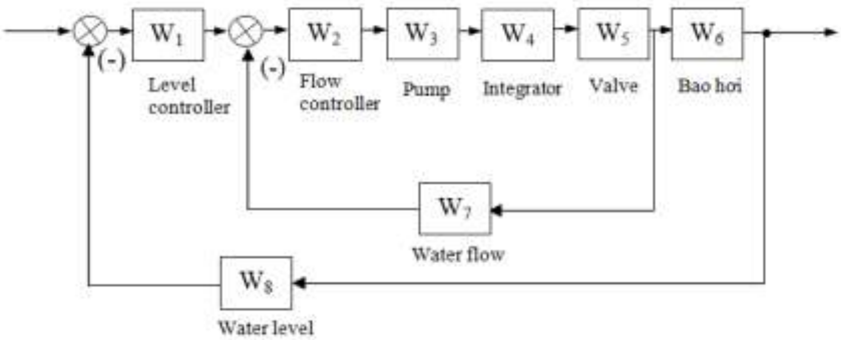

Fig. 4: The schematic diagram of proposed level controller

The transfer functions of elements in the block diagram are written as follows:
W_3 denotes the transfer function of water supply system (Pump in the Fig. 4).

$$W_3(s) = \frac{k_3}{T_1T_2s^2 + T_2s + 1}$$

Because the input signal of the valve is the angular velocity, while the output signal of the power transmission is the speed, an integration block is added with the transfer function W_4:

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

Next, in the valve, the input signal is the angular velocity, whereas water flow plays output role. And, the relationship between the output signal and the input signal of the valve is a first-order inertial equation has the form of W_5:

$$W_5(s) = \frac{k_5}{T_5s + 1}$$

In the steam boiler, the water flow is the input element. The water is transferred into steam. The output signal is the steam flow. The relationship between the output signal and the input signal is a first-order inertial equation with delay is determined by W_6

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

The input signal of the W_7 sensor is the water flow, while the itsoutput signal is the DC current, so the transfer function of the W_7 flow sensor is:

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

Similarly, the input signal of the W_8 level sensor is the water level, and the output signal is the DC current, so the transfer function of the water level sensor is W_8:

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

III. DESIGN THE CONTROLLER FOR LEVEL AND FLOW CONTROL

1. The control problem

The aim of the level and flow control system in the steam boiler is to preserve water level and the water supply flow to the boiler. The paper introduces a control system including two control loops, where an inner flow control loop (with fast response) and an outer level control loop (with slower response) are shown in Fig. 5

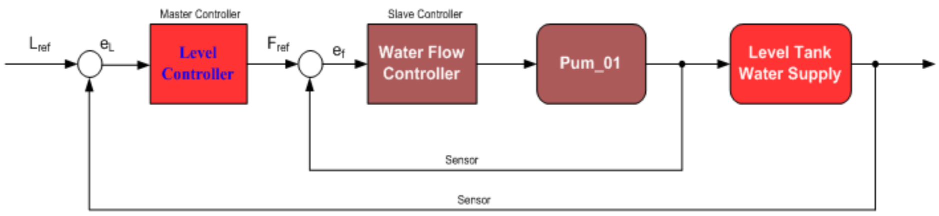

Fig. 5: The cascade control structure diagram

2. Design the PID Controller

In order to meet the heating requirement of the steam boiler, the flow of water supply must be kept stable to ensure sufficient water to the heater. To stabilize the water flow, the pump speed named Pum_01 in Fig. 5 need to be controlled according to the reference flow.

Designing the inner flow control loop is performed as Fig. 6, and the PID controller applied for the outer level control loop is built in the block diagram as Fig. 7 with the simulation result of the system response as in Fig. 8.

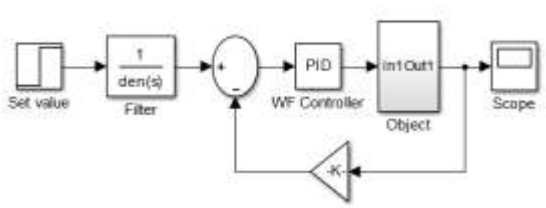

Fig. 6: The flow control loop

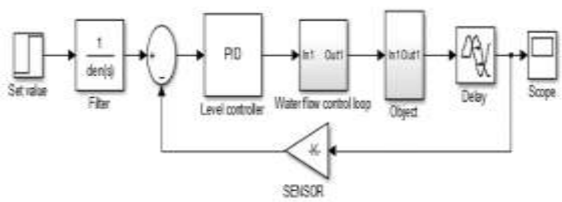

Fig. 7: The level control loop

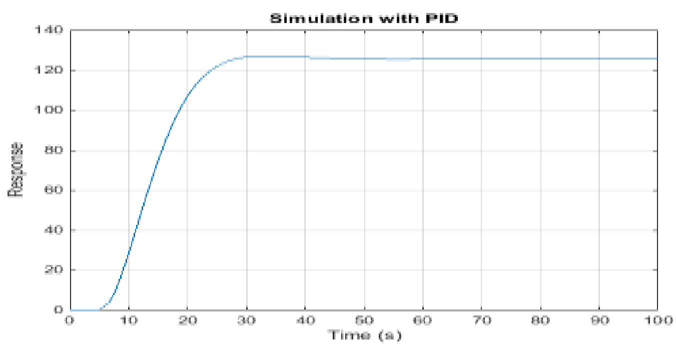

Fig. 8: The response of system with the PID controller

The simulation result demonstrates that the response of the system tracks the desired value and is kept stable, meaning that the overshoot and settling time meet the demands.

3. Design the FLC Controller

The Fuzzy Logic Controller (FLC controller) used in this research consists of two inputs and a output defined as Fig. 9. The input variables are the control signals of the fuzzy controller, which is the control voltage error (ET) and the derivative of the error (DET); and output variable is the control voltage U.

Firstly, the number of fuzzy sets for each language variable is selected as 7 sets with the 7 language variables in each term named as follows: AL, AV, AN, K, DN, DV and DL attached to membership functions as Fig. 10.As we know, the number of fuzzy rules tends to infinity; in this case, we make 49 control rules written.

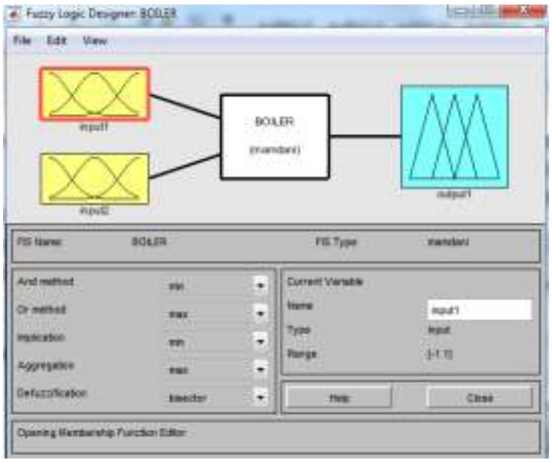

Fig. 9: The input and output variables of the FLC controller

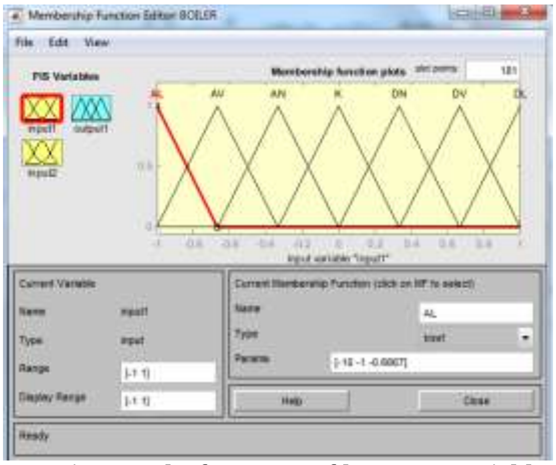

Fig. 10: The fuzzy sets of language variables

This control rules express input-output relationships observed in Fig. 11 and Fig. 12.

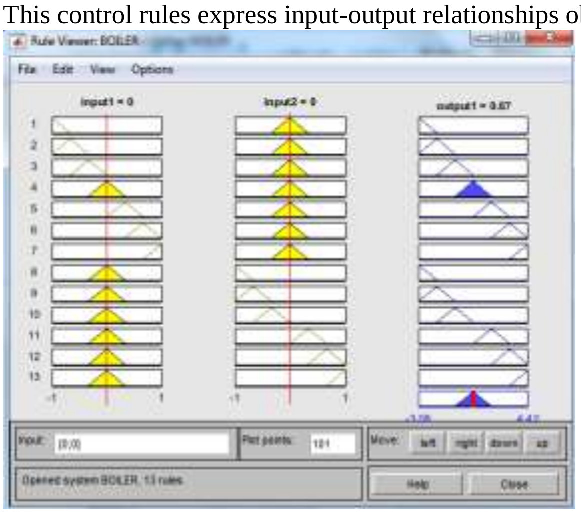

Fig. 11: The input-output relationship with the control rules

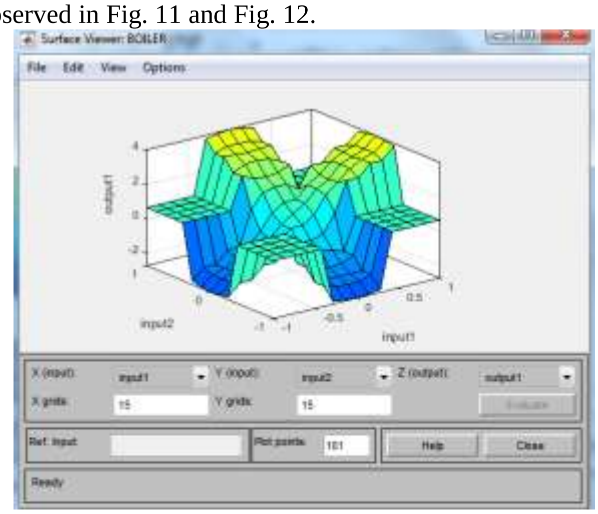

Fig. 12: The equivalent input-output relationship

Simulating control algorithm is implemented by the simulation diagram in Fig. 13 and the simulation result obtained as Fig. 14.

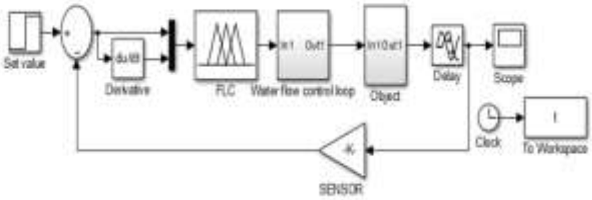

Fig. 13: The simulation diagram in MATLAB/Simulink

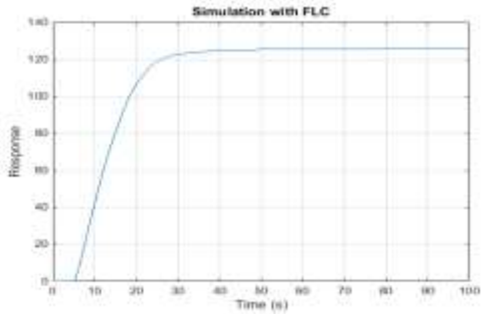

Fig. 14: The response of system with the FLC controller

The system response shows that the FLC controller designed for the steam boiler offers a high performance with low overshoot and short settling time.

IV. EXPERIMENT

Experimental study on the water level controller has been conducted in the laboratory of the electrical engineering faculty, Thai Nguyen University of Technology taken in the Fig. 15 and Fig. 16.

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Fig.15: The experimental model controlling water level

Fig.16: The level tank in the level control model

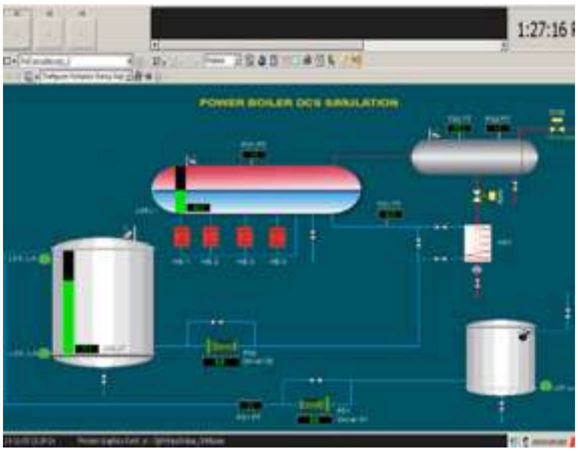

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Fig.17: The level control programming interface

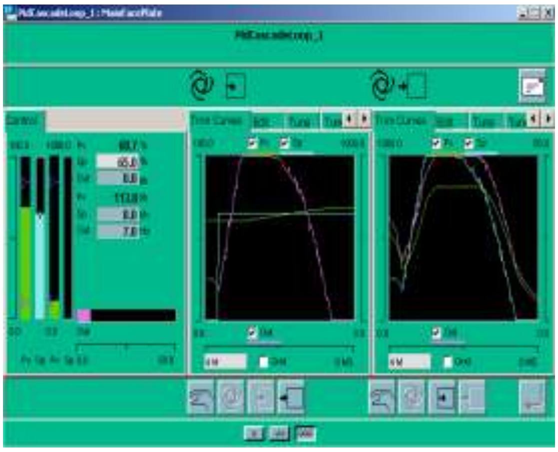

Fig.18: The experimental result with the PID controller

After designing and running the system, the simulation results satisfy reference quality targets. As a result, the proposed controller can be considered as appropriate to the control problem of the steam boiler in the thermal power plant.

V. CONCLUSION

The level control algorithm for the steam boiler in the thermal power plant has been developed and designed by the PID and FLC controller. The design sequence is done through the simulation steps on MATLAB/Simulink and experimental devices in the laboratory to verify the theory and demonstrate the effectiveness of the control algorithm.

The simulation and experimental results show that PID and FLC controllers meet well the control requirements.

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Nguyen Vinh Thuy." Design A Controller Applied For A Water Level Control System In A Thermal Power Plant."American Journal Of Engineering Research (AJER), Vol. 7, No. 6, 2018, PP.269-274.