Boiler level control system based on ControlLogix5550 PLC

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***Abstract*—This paper is a research design based on EFPT process control device. In the design, actual industry field has been simulated and corresponding modelling has been carried on for the boiler level system. Then the appropriate PID parameter has been sorted out and ControlLogix5550 PLC has been used to control the entire boiler level system. At last, a corresponding control interface has been established and the boiler level has been under a safe and accurate control.**

***Keywords* —EFPT; Boiler level; Modelling; PID**

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1 Introduction

The task of the industrial boiler level control is to maintain a dynamic balance by controlling the water flow and evaporation, so that the drum level can be maintained in the technological level, which is a necessity for ensuring safe operation and also one of the main indicators of the boiler's normal operation. Water level which is too high will affect the effect of the steam-water separation, but too low it is will break ring cycle or even cause boiler explosion. To ensure a safe and efficient production, the boiler level must be strictly controlled in maintaining constant or changing only according to a certain rule.

Using Logix5550 PLC with analogy I/O modules, launched by Rockwell Automation Company as controllers, and EFPT process control experimental device as control object, this system have brought the boiler water level under an accurate control in a mini boiler system with sensors and actuators that used in industrial production.

2 System Overview

This system is composed of an EFPT process control device, an inverter, a Logix5550 PLC and a computer. EFPT process control device is a simulated heating and water supply and drainage system for a micro-small boiler. It realizes process control in a mini boiler system with sensors and actuators used in industrial production. The actuator includes not only measuring appliance, but also AC inverter, heating controller, heater and so on. The system simulates industry scene through a mini-boiler heating, water supply and drainage system, which is reliable and visual.

In the design, boiler Level was selected as the controlled variable. The controlled object is composed of the water trough, the force pump, the boiler and the pipe-line valve. Micro Master 6SE9214-0DA40 inverter is taken as the actuator and the boiler level is controlled by Logix5550. Configuration software RSView32 and touch screen PanelView1000 are combined to realize the real-time monitoring. In the design, a simple design of single-loop boiler liquid level value adjustment is selected for the study. The composition of the system is shown in Fig. 1.

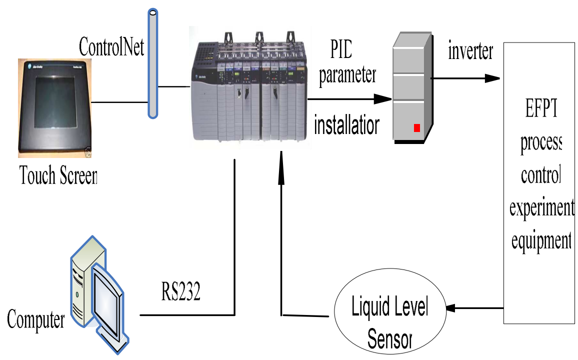

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Fig. 1 Boiler level setting value adjustment system

In the design, the inverter as an actuator directly receives PLC analogy I/O port output, and converters into frequency of inverter so as to drive the 3-phase motor in the lift pump, change the inlet, and adjust the boiler level to the dynamic balance at last. And the configuration software is used to design monitoring picture to realize the computer and the touch screen to the boiler level long-distance and the scene monitoring.

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3 Establishing Mathematics model for the charged object

One of the main tasks of establishing control system mathematical model is to determine the mathematical model of the controlled object. Generally, there are two kinds of basic methods for establishing process control mathematical model: mechanism analysis and experimental method. However, for controlled object whose structure and internal process is very complex, it is very difficult to determine the object just by its own internal physical process and to solve out the differential equations systematically. Besides, considering the nonlinear factor, mechanism analysis used some approximation and hypothesis for mathematical deduction. Although these approximation and assumptions have practical basis, but not fully reflect actual situation, and even cause incalculable effects.

Therefore, in this design, the experimental method is chosen to establish a mathematical model for controlled object. This kind of modelling is based on the input and output in the actual production process, that is to say, establishing mathematical model for the controlled object through process identification and parameter estimation. In this design, step response curve method is used to identify mathematical models of the process. A 20Hz step disturbance input signal is applied to the charged object, and the response curve of the output that changes with time can be mapped. After the analysis, the transfer function of the controlled object can be defined. In the process of experiment, the object was conducted several tests. Using RSLogix5000 trend monitoring function curve, more than 10 charged object step response curve have been recorded. To all the parameters for average, steady time: $t_s \approx 821.525$s, steady value: h（∞）=58.5, peak time: $t_p=394.4$s overshoot: σ%≈29%. According to the theoretical analysis, the controlled object is the most likely second-order object.

However, the difference is very apparent between the ideal second-order controlled object step response curve and the actual curves. So the ideal curve can't response to its actual characteristics. It is inferred that the controlled object may be the second-order controlled object that includes zero. The try and error method and MATLAB simulation tools are used to get a curve whose parameters are close to the average dynamic parameters of the controlled object's response curve. It is shown in Fig. 2.

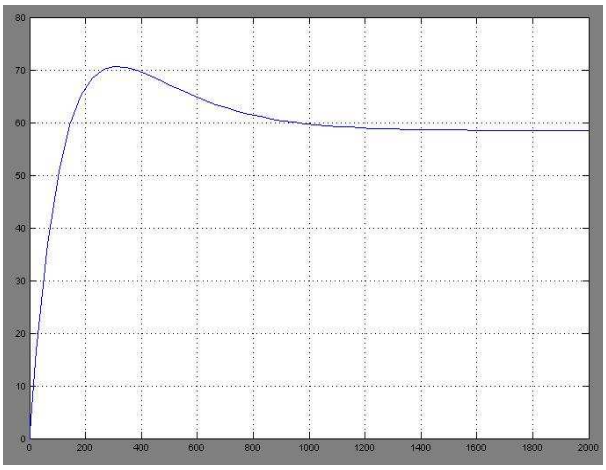

Fig. 2 The MATLAB gather try curve of controlled object

According to the figure, the approximate transfer function of the controlled object is

$$G(s) = \frac{0.038(s+0.0025)}{(s+0.005)(s+0.0085)} \tag{1}$$

Some adjustments can be made according to the following rules:

1) When the zero is closer to the imaginary axis, settling time will be longer and the overshoot will be bigger and peak time will be smaller. With the zero closing to the imaginary axis, the effect is more obvious.

2) The effect which the closed loop dominant apices have on dynamic performance is increasing the peak time, reducing the overshoot and adjusting time. Nonparametric model is used to describe the controlled object. In other words, step response curve which approximately describe the controlled object is used because of the controlled object's complexity and uncertainty.

4 The installation of controller parameter

4.1 The selection of control algorithm

After establishing the approximate mathematical model of the controlled object, a complete feedback control system can be formed to improve the performance of the open-loop control system. PID is an ideal control law in that integral is introduced basing on the proportion, which can eliminate the residual error, plus the derivative action, which can also improve the stability of the system. According to the characteristics of the controlled object and laboratory conditions, a single-loop feedback control loop for the controlled object is established, and PID algorithm is used to realize boiler level control. The schematic diagram of level control is shown in Fig. 3.

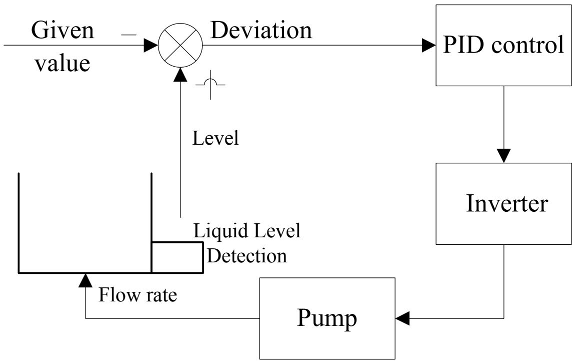

Fig. 3 The schematic diagram of level control

Open the outlet valve to a certain degree, and make the hydraulic discharge invariable. Comparing the process variables of the water level in feedback with the given volume, the deviation can be obtained. PID instruction does PID operation on the deviation, and the results is a control variable, so the frequency of the inverter can be changed to control the rotate speed of the pump. If the liquid level is on the high side, the results make the control variable smaller, and reduce the rate of inflow, make liquid level lower; if the level is on the low side, the results make the control variable larger, and increase the rate of inflow, make liquid level higher.

4.2 The Parameter Tuning of PID

Because the transfer function of the controlled object includes a zero second-order link, the computation work load is quite big regardless of using the root-locus method or the frequency characteristic law among theory methods when tuning PID parameter. And the process mathematical model can only reflect dynamic parameter approximately, so the reliability of the parameter value which is obtained by the theoretical calculation is not very accurate and it will be adjusted constantly in the scene. Therefore, engineering parameter tuning is chosen to seek the PID parameter in the design. The common method of engineering tuning are dynamic characteristic parameters, the stable boundary law, the decay curve law and field experience settingmethod, etc. In the process of PID parameters, the 4:1 decay curve law is adopted. The steps are:

1) In the closed system, regulator's integral time is set the largest (Ti=∞) and differential time Td is set zero (Td = 0). The proportion is taken the great value to perform the given value perturbation experiment repeatedly, and the proportion is reduced gradually until the record curve presents up to 4:1 weaken. Then the proportion is called 4:1 weaken proportion δs and the distances between two neighboring wave ridge's are called 4:1 damped cycle Ts. In the experiment, the level quantitative test is set for the 200mm, and then the system response curve is obtained and reorganized 4:1 decay curve (thick red line) is shown in Fig. 4.

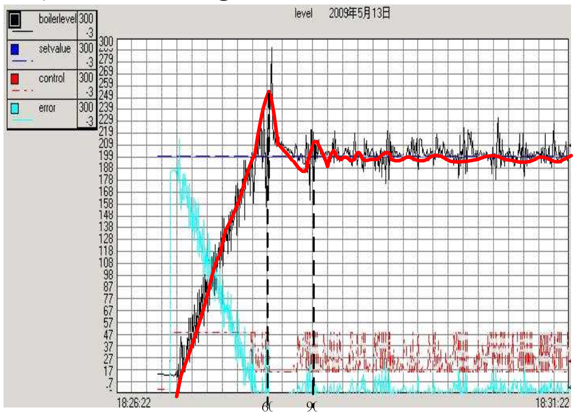

Fig. 4 4:1 decay curve

Thus measuring:δs≈8，Ts≈2.2;

2) According to the following formula, each parameter of the regulators is

δ=0.8, δs≈6.4;

Ti=0.3, Ts≈6.6;

Td=0.1, Ts≈2.2;

3) According to these results, regulator parameters are set. Then the dynamic process of system is observed and the parameters are made adjustment to determine the optimum parameters.

5 Monitoring Design

RSView32 software and PanelBuilder32 software of Rockwell Automation Company are respectively used to design monitor screen to complete such function as animating display, parameter setting, report output, the current curve display and history curve display and so on，and make the computer and touch screen achieve the remote and on-site control to the boiler liquid level. The picture screen of system monitor is shown in Fig. 5.

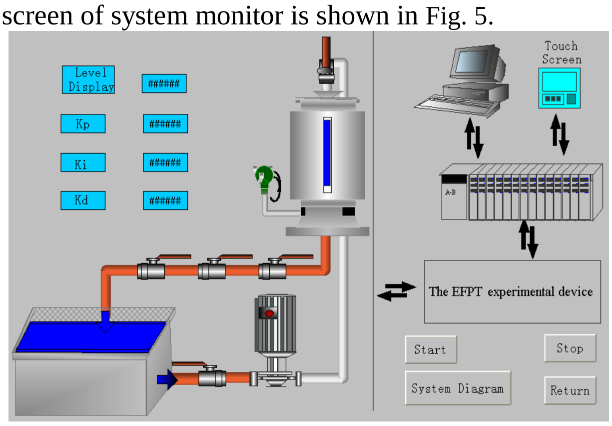

Fig. 5 The main picture of system monitor

The main work of realizing configuration is to establish level control objects and make animating display scenes. Controlled objects include inletting water flow, exporting water flow and the numerical object of the boiler level. When animation connection is established, the basic graphic elements and animation component library are called in the user window to construct configuration diagram. Graphic objects and data objects defined by the state are set in the state of the corresponding attribute and animation connection is defined. Having finished the design of the developing system, you can switch to run mode to carry on the real-time monitoring to the control system and test configuration.

6 Conclusions

This paper has introduced the composition and running of EFPT process control system based on ControlLogix5550 PLC control, the mathematical model establishing of controlled object and the parameter tuning of PID. The use of configuration software extends the communication function. Through experimental testing, the control curve's overshoot is small and the transition time is short, so the control effect is quite ideal. This device being reliable and intuitive is suitable for scientific research and teaching, and has important application value in the actual industrial production.

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