An **Real-time Embedded Control Systems for Liquid-location and Discharge of Boiler**

Xiao-Jin Fu, Xin-Hua Zhang

***Abstract*—This paper introduces an real-time embedded control systems for the liquid location, pressure and discharge of boiler in the power plant, as well as the characteristics of the monitor and control system. By providing both the hardware and software, this paper also studies the use of computer and fuzzy control technology, in order to meet the requirements of liquid location, pressure and discharge change while the boiler of the small or medium-sized power plant is in operation.**

***Index Terms*—boiler; liquid-location; embedded systems; monitor-control; fuzzy control**

I. INTRODUCTION

To monitor and control the liquid location, pressure and discharge of the boiler is an important part in the operation of the boiler in power plant. Liquid location and discharge influence each other, so do pressure and temperature, while monitoring the liquid location is mainly connected with discharge. When the liquid location of boiler is low, the discharge should be adjusted the lower value. This paper introduces a monitoring and controlling system of the liquid location and discharge of boiler. The construction of the system is indicated as follows[1~3]:

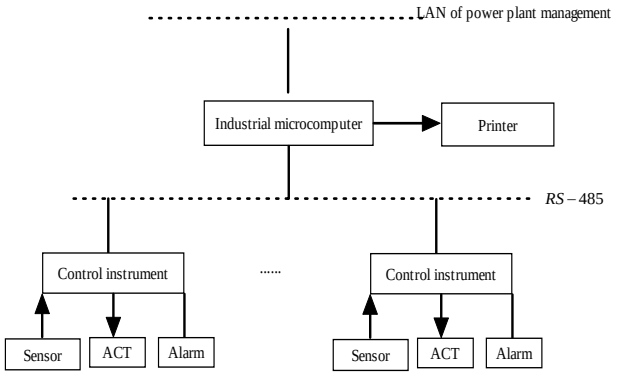

Fig.1 Monitoring system of liquid-location and discharge

In the process of operation, the boiler should be controlled in terms of the change in liquid location and discharge to ensure its normal operation. In the actual observation, the liquid location and discharge are not only influenced by control, but they[4] influence each other as Figure 2 indicates:

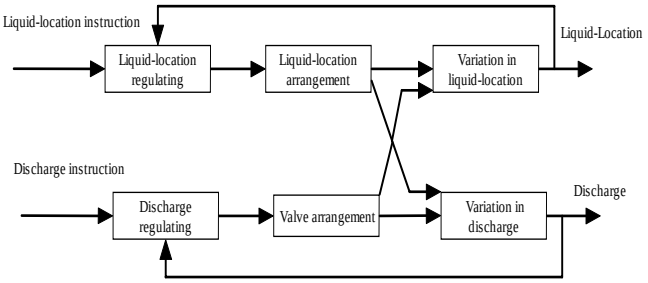

Fig.2 Coupling phenomena of discharge and Liquid-Location of boiler

While controlling the liquid location of the boiler, a change of liquid location will take place with the inflow of boiler water and the outflow of steam and hot water. The height of liquid location will affect the volume of discharge, which makes it difficult for the conventional control to work. To solve this problem, we have therefore developed the monitor and control system of the liquid location and discharge, based on the fuzzy and decoupling control.

II. THE THEORY OF CONTROL

Fuzzy control is adopted in this system as Figure 3 indicates.

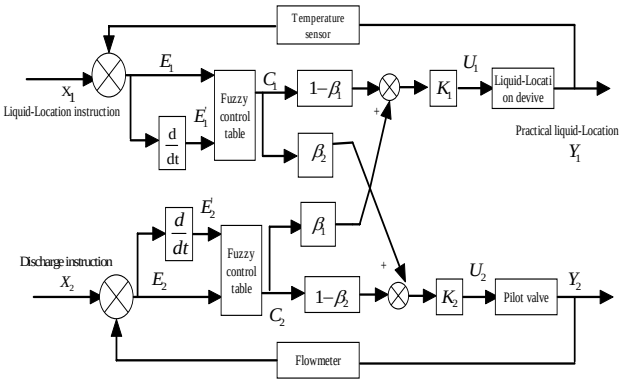

Fig.3 Principle of control

Supposed that E_1 and E_2 indicate liquid-location and discharge respectively, and that $E_1^{'}$ and $E_2^{'}$ indicate the rate of change of deviation with respect of time, while the C_1 and C_2 indicate control output of the liquid-location and the discharge too. if various kinds of state of the above variable ,such as positive big, positive median and positive small, and

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F.A. Dept. of Mechanical & Electrical Engineering, Shaoxing College of Arts and Sciences, Shaoxing, 312000, China. (phone: 86-0575-8318180; fax: 86-0575-8318180; e-mail: fuxiaojin8@hotmail.com).

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positive zero and zero and negative zero, and negative small and negative median and negative big, express respectively in PB and PM and PS and P0 and 0 and N0 and NS and NM and NB ,the empirical fuzzy control rule can be generalized from the control experience to the liquid-location and discharge, whose deviation and change are described by the way of discrete and fuzzy in the system. Whereas the input and output system practically are continuous. Therefore, change the variables into corresponding fuzzy subset, and give a definition of them ,and set the degree of membership of the kinds of fuzzy variables in the field of definitions, and then calculate the corresponding fuzzy controlled quantity of the above variables by the way of discrete.

Fuzzy subsets of the above variables are defined as follows:

$$\{E_1\} = \{E_1^{'}\} = \{NB, NM, NS, N0, 0, P0, PS, PM, PB\} \quad (1)$$

$$\{E_2\} = \{E_2^{'}\} = \{NB, NM, NS, 0, PS, PM, PB\} \quad (2)$$

$$\{C_1\} = \{C_2\} = \{NB, NM, NS, 0, PS, PM, PB\} \quad (3)$$

The universe of discourse prescribed is

$$E_1 = E_2 \quad (4)$$

$$E_1^{'} = E_2^{'} \quad (5)$$

$$C_1 = C_2 \quad (6)$$

The degree of membership that corresponds to the fuzzy variable adopts the method of Gaussian distribution. So the fuzzy relation matrix can be obtained by the fuzzy control computation rule [5~7]:

$$R_1 = \prod_{i=1}^{k} r_i = r_1 \bigcup r_2 \bigcup \cdots\cdots \bigcup r_k \quad (k = i \bullet j) \quad (7)$$

$$R_2 = \coprod_{i=1}^{k} s_i = s_1 \bigcup s_2 \bigcup \cdots\cdots \bigcup s_k \quad (k = i \bullet j) \quad (8)$$

In the formulas:

$$r_i = E_1(i) \times E_1^{'}(j) \times C_1(i.j) \quad (9)$$

$$s_i = E_2(i) \times E_2^{'}(j) \times C_2(i, j) \quad (10)$$

The value of variables that in the above expressions, such as $E_1(i)$, $E_1^{'}(j)$ and $C_1(i, j)$ and $E_2(i)$ and $E_2^{'}(j)$ and $C_2(i, j)$,can be obtained according to the corresponding designation of the degree of membership respectively, so the corresponding fuzzy control can be gained:

$$C_1 = (E_1 \times E_1^{'}) \times R_1 \quad (11)$$

$$C_2 = (E_2 \times E_2^{'}) \times R_2 \quad (12)$$

The fuzzy control table will be generated on principle of picking up the maximum of membership function from $C_1(i, j)$ and $C_2(i, j)$,and then be saved into computer. The corresponding control to liquid-location and discharge can be obtained from fuzzy control table, which on the base of the detection and variance ratio of liquid-location and discharge.

In the terms of the control to the above results of the liquid-location and discharge, the control to decoupling can be realized by the link of decoupling β_1 and β_2 .The procession of control is shown in Fig.3[2].then the actual output is:

$$U_1 = K_1[(1-\beta_1) \times C_1 + \beta_1 \times C_2] \quad (\beta_1 = 0-1) \quad (13)$$

$$U_2 = K_2[(1-\beta_2) \times C_2 + \beta_2 \times C_1] \quad (\beta_2 = 0-1) \quad (14)$$

It's apparent that $U_1 = K_1 C_1, U_2 = K_2 C_2$, when $\beta_1 = \beta_2 = 0$, which equal to the case of having no effect on decoupling, and is shown in Fig.2 that is controlled by two single circuit. In the same time, corresponding to the case of limit coupling there is $U_1 = K_1 C_2, U_2 = K_2 C_1$, when $\beta_1 = \beta_2 = 1$ .While the actual value of β_1 or β_2 ,which between 0 and 1,is established by a series of specified experiment on the boiler in advance. The method, which be introduced usually is as follows: at first, supposed $\beta_1 = \beta_2 = 0$, performing experiments on the boiler that cause the biggish fluctuation of the liquid-location and discharge, then increasing the value of β_1 and β_2 gradually in order to decrease the fluctuation.

III. THE DESIGN OF SOFTWARE

The system software consists of master module, manual module and parameter setting module, and can be switched to each of the modules. The master module performs the function as follows: automatic detection, control and give an alarm in the case of transfinite to the liquid-location, pressure and discharge. The PC104 embedded systems compares the gathering signal about liquid-location and discharge with default curve in the first, and then forms the deviation signal E_1 and E_2 ,and searches for the corresponding controlled object from fuzzy control table in the next, and forms the control output to drive the ACT in the end. The alerting module will give warning of the transfinite case of the liquid-location , pressure or the discharge by the lamps, and in the same time take measures to meet the situation. The manual module provides the function of control of manual intervention in particular cases. The monitor software is developed in the language of C in the system. The data flowchart see Fig.4.

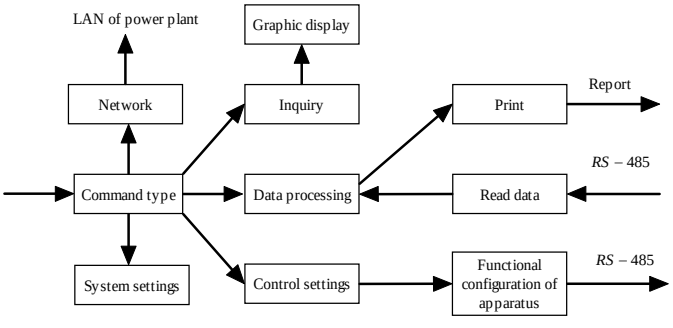

Fig.4 Data flowchart of monitoring system

The section of display contains many screens such as history graph, tendency chart and stick plot, and analogue instrument diagram, and operating instruction, and flow chart, etc.

The function program completes such functions as the calculation to the liquid-location , pressure and the discharge, the print to the report and the setting to the controls parameter, and so on. In the same time, there is a series of buttons that corresponds to each function. Consequently, the operator can conveniently achieve the functions such as command execution and picture display by pointing to the corresponding button with the mouse.

IV. APPLICATION

This system can be applied to the technological transformation of medium-sized power plant, which realizes the field monitoring, long-distance supervisory control and giving an alarm of transfinite acousto-optic to the liquid-location and discharge of the boiler. In addition, the continuous regulator of liquid-location and discharge will provide input signal in order to accomplish the purpose of adjustment as the situation requires.

The automatic monitoring system can strengthen the scene level information integration ability, and in the same time gain the massive rich information, and then realize information transmission of the equipment condition, the breakdown and the parameter. The system not only completes the short range or the long-distance control, but also may complete the short range or the long-distance parameterized work. Meanwhile, the system has the properties such as openness, interchangeability and maneuverability, and integration .The reliability of the system is high and the maintainability is good, which reduces the number of wiring point and the expense of cable laying project, and the cost of the system and the project. In addition, the software and hardware of the system have the interoperability.

The software, with running on the PC 104 embedded systems platform, no long bands together with the control instrument and sensor ,etc, and moreover, the software have the general automatic software platform which possesses standard communication protocols, basic programming language and uniform surface style, and standard data format and database interface. Besides, the software is open style, and allows the private automatic software to inset in the PC 104 embedded systems.

This system can bring a positive effect for the automatic control of boiler of the power plant, and the control on liquid location, pressure and discharge can guarantee the safe and reliable operation of boiler.

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