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Intelligent Control System of Stack-boiler

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Abstract

Boiler combustion control system’s basic task is to make fuel burn calories adapt to the needs of the water temperature and ensure the economical combustion and the safe operation. In the foundations which have analyzed the stack-boiler’s work process and control system structure, the system designed by using the self-learning and self-optimizing fuzzy control system of the PC to make air/coal ratio achieve the best and realize the optimized combustion; through PLC to accelerate the speed of response to the boiler, and speed up the PC to optimize the speed and realize the double loop control system for stack-boiler. The control system in premise of the stack-boiler reaches the goal of the load to achieve the highest efficiency of the boiler combustion.

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1. Introduction

Stack-boiler is used as our main furnace type in heating system of our country and the goal we research it is to ensure the safe and stable operation, and with the fewest number of coal consumption and minimize power consumption to meet the demand of user. Stack-boiler is influenced by many unfavorable factors, such as pure delay, various coal and load change frequently and its combustion
process is a complex system of a multi-input, multiple output, multi-loop, nonlinear and mutual cross-coupling, these give control has led to great difficulties. Intelligent control method has good control effect for serious non-linear, time-varying and uncertainty of the system. By using this method does not need to do detailed analysis on the object model and does not need to do a variety of interference with decoupling, just add certain self-learning function, simulation of experts and operator's experience, can make the control achieve rapid, high precision and small overshoot. This method was widely applicable and strong robustness. This system combines self-learning and self-optimizing with intelligent control and adds it into the combustion control of stack-boiler. This system has actual operate in HUHHOT FUTAI Heating Company. Operation results show that the control system has strong adaptability, dynamic characteristic and steady characteristic can be balanced with each other and achieved satisfactory effects of operation.

2. System Design

According to the Stack-boiler process requirement and the actual situation, in order to ensure the Stack-boiler control system is safe, reliable and efficient operation, the control system adopts upper computer and lower computer two-level control mode. Lower computer use PLC programmable controller, the upper computer use industrial computer finish configuration of lower computer, written of control procedures, production flow chart, dynamic display of analog signals and switch signals, display of real-time trends, query of historical data etc, then output control signal for lower computer to run. When the upper computer is at fault, lower computer can also control the operation of boiler independently, namely realized double-loop control system of boiler.

Structure diagram of system shown in Figure 1.

![Fig.1 Structure diagram of system](image)

3. Control System

This system is on the basis of relying on strong judgment rules and using real-time 4 times curve fitting for output signal preprocessing of boiler. When the boiler loads variable run-time, it can direct inquire a record of self-learning functions and control boiler operation. When the system is stable, take seek the efficiency of boiler most to be high as the goal, through the blast volume of fuzzy self-optimizing
control methods to make the ratio of air-coal achieve the best value, realize the optimized combustion and simultaneously renew the load correspondence table.

Control process flow of system shown in Figure 2. This flow according to the target load is change or not to decide to call a record of self-learning functions or run self-optimizing system which is set the highest efficiency as goal. The middle part of flow is self-optimizing system, when through optimal get the output power of Stack-boiler does not meet the goal, and then invoke the judgment rules of flow on both sides to Change coal and air on Proportion.

3.1 Target load setting system design

Based on heating principle of the heat balance, the actual heat of boiler should be consistent with the heat load. Conventional hot water boiler’s control schemes often ignore the affect of return water temperature and water flow in the boiler, use boiler water temperature control heat load. In the actual operation, when the return water temperature or water flow changes greatly, this scheme difficult to achieve accurate control of load. In order to overcome the disadvantages, this scheme adopts the boiler heat output to control the load. According to the outdoor temperature of real-time, total heating areas of user set, transmission losses and other parameters to calculate the total target load of heat.

3.2 self-learning load table design

When the boiler load occur disturbance, system first inquires the self-learning load table output control quantity to control coal and air. The control volume of self-learning load table is the optimal value of last system optimization, so quick to make the boiler to reach the vicinity of the optimal value of this condition. Until the system is stable, then by self-optimizing fuzzy controls system to seek the optimal value of combustion status.

3.3 Fuzzy Self-Optimizing Control System design

The fuzzy self-optimizing control of this system is a dynamic control scheme which is combined self-optimizing system with fuzzy control system. It is an automatic control method which is in the situation of using zirconia as oxygen to measure air/fuel ration is not accurate, to make the air/fuel ration follow the stack-boiler combustion condition’s change automatically adjusted and make Stack-boiler reach efficient operation. To search for the best air/fuel ration under different conditions, a single variable (air) optimization will be able to meet our requirements. In the actual control process, fuzzy variable step self-optimizing using the following control ideas and steps.

- First make a tentative control, increase or decrease the air, and then observe the change of stack-boiler’s output power to do next control.
- Fuzzy quantization. The collected flow and temperature signals through data pretreatment are putted into program arrays, through the formula to calculate $\Delta w_i'$, then into the fuzzy quantization process, and corresponding to fuzzy language word sets.
- Judge the symbols of $\Delta w_i'$. If $\Delta w_i' > 0$, show that at this time the boiler’s efficiency did not reach the optimal and the system is in the stage of increasing efficiency. Therefore, the next-step control does not change the control direction and just change the size of the control volume. If $\Delta w_i' < 0$, there are two kinds of possibility: one kind is that the direction is reverse, and explain that the efficiency of boiler is decreasing at this time; The other is the Change of blower’s frequency is too large, the heat taken away by the excessive air is too much, not the boiler’s efficiency is actual in decline. Therefore, at this time still need to determine is what kind of situation. Maintain the
original direction and reduce the blower’s frequency, if $\Delta w_i > 0$, then belongs to the second case, the next step according to the direction of control at this time; if $\Delta w_i < 0$, at this time can be regarded as the boiler’s efficiency is indeed on the decline, the next step is controlled by the reverse.

- Step in fuzzy controller. When the system is stable, fuzzy self-optimizing controller’s output is the blower’s frequency, and two inputs are heat signal and the previous step’s frequency of blower, the heat signal and the previous step length to determine the blower’s frequency of this step.
- Clarity. Make blower’s frequency clear and output precise control volume to regulatory agencies to control the change of blower’s frequency.

The flow of fuzzy self-optimizing control system is shown in Figure 3.

![Fig.3 Fuzzy self-optimizing control flow](image)

Fuzzy self-optimizing control system block diagram shown in Figure 4.
The design uses heat signal’s increment $E_1$ and the last bow frequency’s increment $E_2$ as a fuzzy controller’s input, output language variable is the air/fuel ration’s variation $UC$. For the air conditioning system selected a dual-input single-output fuzzy controller.

Fuzzy self-optimizing control rule table is shown in Table 1, control table shown in Table 2.

Table 1. Control rule table of fuzzy self-optimizing air/fuel ration

| $E_1$ | $E_2$ | NB | NM | NS | PS | PN | PB |
|-------|-------|----|----|----|----|----|----|
| NB    | PB    | PB | PB | NB | NB | NB | NB |
| NM    | PM    | PB | PB | NB | NB | NB | NM |
| NS    | PS    | PM | PM | NM | NM | NS | NS |
| NO    | PS    | PS | PS | NS | NS | NS | NS |
| PO    | NS    | NM | NM | PM | PM | PM | PM |
| PS    | NS    | NM | NM | PM | PM | PM | PS |
Table 2. The control table of self-optimizing air/fuel ratio

| E   | -6 | -5 | -4 | -3 | -2 | -1 | 1  | 2  | 3  | 4  | 5  | 6  |
|-----|----|----|----|----|----|----|----|----|----|----|----|----|
| E1  | -6 | 6  | 6  | 6  | 6  | 6  | 6  | -6 | -6 | -6 | -6 | -6 |
|     | -5 | 6  | 6  | 6  | 6  | 6  | 6  | -6 | -6 | -6 | -6 | -6 |
|     | -4 | 4  | 4  | 5  | 5  | 6  | 6  | -6 | -6 | -5 | -5 | -4 |
|     | -3 | 4  | 4  | 5  | 5  | 6  | 6  | -6 | -6 | -5 | -5 | -4 |
|     | -2 | 1  | 1  | 3  | 3  | 4  | 4  | -4 | -4 | -3 | -3 | -1 |
|     | -1 | 1  | 1  | 3  | 3  | 4  | 4  | -4 | -4 | -3 | -3 | -1 |
| 0   | 1  | 1  | 1  | 1  | 1  | 1  | -1 | -1 | -1 | -1 | -1 | -1 |
| 1   | -1 | -1 | -3 | -3 | -4 | -4 | 4  | 4  | 3  | 3  | 1  | 1  |
| 2   | -1 | -1 | -3 | -3 | -4 | -4 | 4  | 4  | 3  | 3  | 1  | 1  |
| 3   | -4 | -4 | -5 | -5 | -6 | -6 | 6  | 6  | 5  | 5  | 4  | 4  |
| 4   | -4 | -4 | -5 | -5 | -6 | -6 | 6  | 6  | 5  | 5  | 4  | 4  |
| 5   | -6 | -6 | -6 | -6 | -6 | -6 | 6  | 6  | 6  | 6  | 6  | 6  |
| 6   | -6 | -6 | -6 | -6 | -6 | -6 | 6  | 6  | 6  | 6  | 6  | 6  |

4. Conclusion

This system has actual operation in HUHHOT FUTAI Heating Company, through the practical operation results concluded that the control system can fast tracking load, stable and reliable performance, greatly reduce the worker’s labor intensity, and has good practicality, not only can satisfy the customer's requirements, but also save coal consumption and power consumption.

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Fig. 2 System control process flow