2003 International Symposium on Advanced Intelligent Systems
September 25-28, 2003, Jeju, Korea

A Study On the Design Of Fuzzy Controller for the Steam Temperature Process in the Coal Fired Power Plant

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In this paper, we proposed the method to design fuzzy controller using the experience of the operating expert and experimental numeric data for the robust control about the noise and disturbance instead of the traditional PID controller for the main steam temperature control of the thermal power plant. The temperature of main steam temperature process has to be controlled uniformly for the stable electric power output. The process has the problem of the hunting for the cases of various disturbances. In that case, the manual action of the operator happened to be introduced in some cases. We adopted the TSK (Takagi-Sugeno-Kang) model as the fuzzy controller and designed the fuzzy rules using the informations extracted directly from the real plant and various operating condition to solve the above problems and to apply practically. We implemented the real fuzzy controller as the Function Block module in the DCS(Distributed Control System) and evaluated the feasibility through the experimental results of the simulation.

Ⅰ. Introduction

The proper control of the superheated steam temperature process in the thermal power plant is the important loop among the various process control loops. Because the process gives the considerable results for the life and effective operation of the plant. The superheated steam temperature control loop has the characteristics of the large time constant and mutual-interference of the various variables. Especially, there are many related process variables according to the variation of the load in the case of the sliding pressure operation in the plant. In that case, the traditional the PID controller of the analog control system had not the good performance. But the micro processor-based digital distributed control system has been applied to the power plant since the beginning of the 1980's and many kinds of the optimal algorithms have been adopted for the process. From the control system for the simple and independent process in the past, the recent control system is rapidly developed to correspond to the system. But actually, in the case of the variation of the operating points and system parameters such as the various fuels, sliding pressure operation and the response characteristics of the actuators the experiences of the operators and the methods of trial and error have been used for the tuning of the controller. In this paper, we developed the new fuzzy controller for the DCS(Distributed Control System) algorithm applied in the domestic control system that has been replaced for the analog control system. The fuzzy controller has the characteristics of the rapid and robust responses compared to the traditional digital PID controller. We adopted the Sugeno-Takagi-Kang) model for the fuzzy controller[1][2]. We used the fuzzy clustering algorithms for the selection of the rules and the back-propagation neural network algorithm for the setting of the parameter of the rules. We implemented the fuzzy controller in the DCS system (Master P-3000, LGIS). The function block model for the controller has been developed and tested for the performances of the proposed methods. The test bed is composed of the DCS system and the simulator for the thermal power plant[3].

Ⅱ. Design of the fuzzy controller for the main steam temperature process

1. The superheated steam temperature control system

The purpose of the superheated control is to maintain the steam temperature of the outlet of the superheater constant. The Fig. 1 shows the control system.

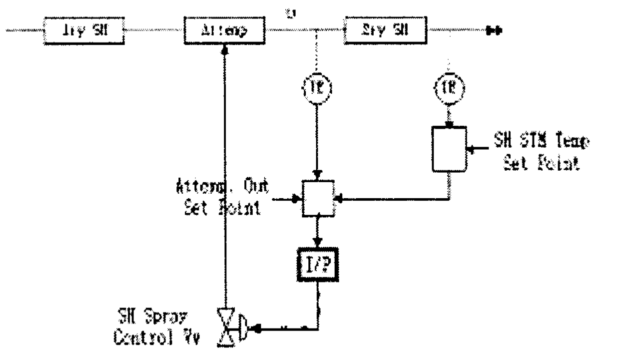


Fig.1. The SH temperature control system

The process variable is the main steam temperature of the outlet of the superheater and the value of the set point is constant 541 ℃. And the attemperator spray water valves that are located in the inlet of the secondary superheater are used for the manipulating control variable. The control logic is composed of the two loops. The output of the first loop (main loop) is cascaded to the secondary attemperator control loop(sub. loop).

2. The fuzzy controller

In this paper, we adopt the TSK(Takagi -Sugeno -Kang) model as the fuzzy controller for the SH steam temperature control process. The rule of TSK fuzzy system can be expressed as follows.

R^n: If x_1 is C_1^n and .... and x_m is C_m^n ,

Then $y^n = c_0^n + c_1^n x_1 + \ldots + c_m^n x_m$ (1)

where C_i^n represents fuzzy set, n is the number of rules, m is the number of input variables and x is the input variable. That is, the if-part of the rule is equal to that of general if-then rules and the then-part is composed of the linear combination of the input variables. The output of the controller is calculated as follows.

$$f(x) = \frac{\sum_{l=1}^{M} y^l w^l}{\sum_{l=1}^{M} w^l} \quad (2)$$

where, the weighting value w^l can be presented by equation.

$$w^l = \prod_{i=1}^{n} u_{c_i^l}(x_i) \quad (3)$$

The membership function of the controller is the gaussian type of the Fig. 2.

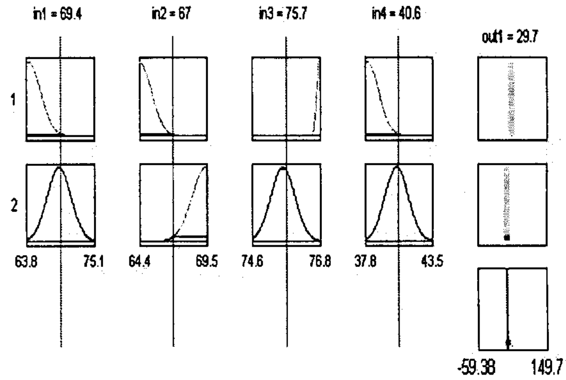


Fig. 2. The membership function for the fuzzy controller

We designed the fuzzy control systems for the steam temperature control system using the above fuzzy model. The Fig. 3 shows the abbreviated structure that is divided into two parts. The main part has 3 input variables of the main steam temperature(M.S.T), the steam flow(S.F), and the steam set point and one output variable of the output of Σ. The sub. part has 2 input variables of the output of Σ and the spray temperature and 2 output variables of the spray valves(V.C.S). The T1,T2 blocks represents the linear transducer. Each control part is replaced by the two fuzzy control system. The main part has 3 gaussian fuzzy sets and rules and the sub. part has 4 gaussian fuzzy sets and rules considering the data analysis.

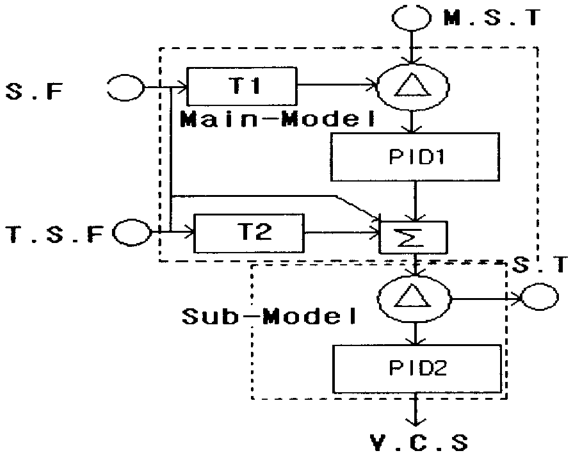


Fig. 3. The brief structure for the main steam temperature control system

Ⅲ. Implementation of fuzzy controller

The fuzzy controller for process control can be implemented as the function block diagram in the DCS system. The output and performance of the fuzzy controller is verified by the MATLAB tool. The following figure shows the definition diagram of parameter for the fuzzy controller.

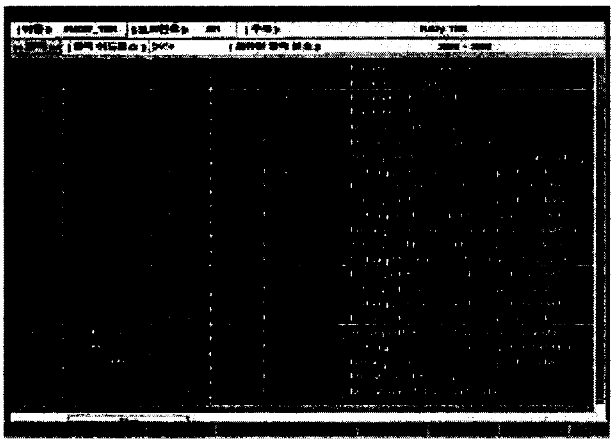
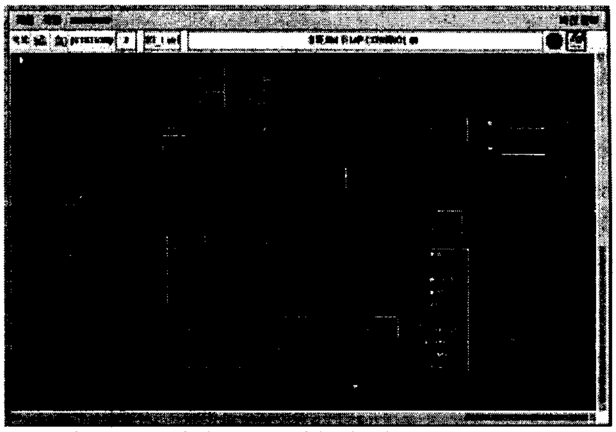


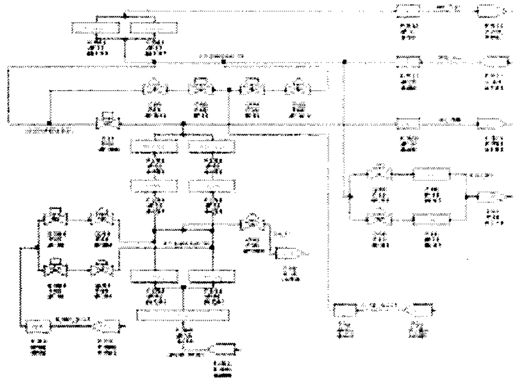
Fig. 4. The definition function block diagram.

Ⅳ. Experimental Results

For the experimental verification, the experimental system is composed of the DCS system and the simulator system. The DCS system is responsible for the control and the simulator corresponds to the process. The following figure shows the experimental configuration for the SH steam temperature control systems.



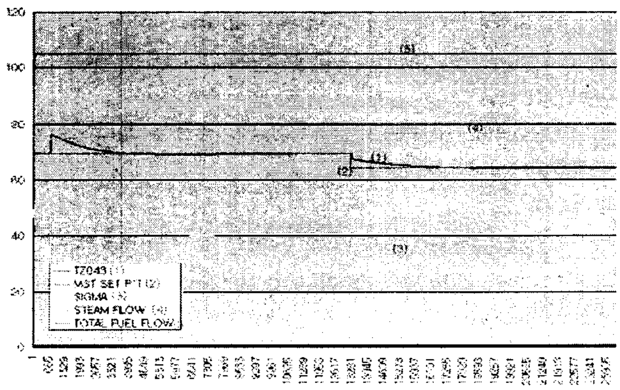
(a) The control function block diagram of DCS



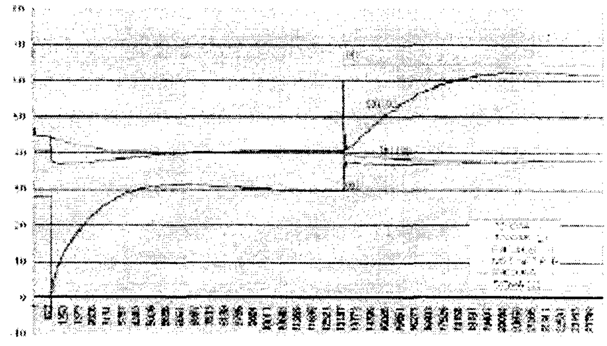
(b) The process of the simulator

Fig. 5. The Experimental configuration Systems

The following figure shows the process characteristics in the simulator. The responses of the closed loop system are shown by the changes of the operating points between 540℃ and 529℃. The system represents the first order system including large time constant.



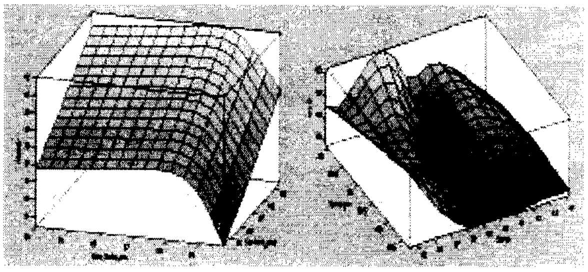
(a) The main Control part



(b) The sub. control part

Fig. 6. The responses of the simulator system

We can get the parameters of the rules for the two fuzzy controllers using a fuzzy clustering algorithm and the previous data. The following figures shows the input-output spaces for the fuzzy controllers. They represents the nonlinear and smoothing characteristics of the relations between the input and the output.



(a)The main part (b)The sub. part

Fig. 7. The input-output space for the fuzzy controller

The Fig. 8. shows the result of the case of applying the fuzzy controller in the DCS. We can obtain the rapid response compared with the simulator control system.

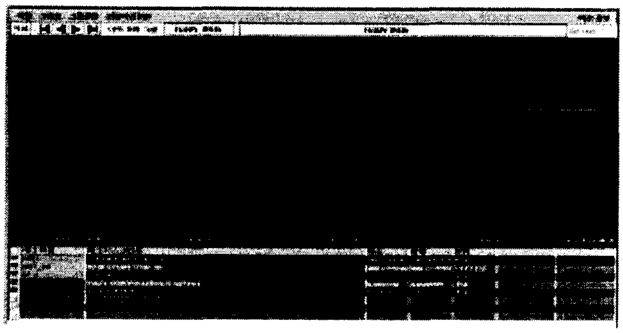


Fig. 8. The responses of the fuzzy controller

V. Conclusion

In this paper, a fuzzy controller for the superheated steam temperature process is developed. And the controller is implemented in the function block of the DCS. The experiment has been achieved the through composition of the DCS and the simulator. The result has shown the good efficiency of the fuzzy controller.

References

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