IJETST- Vol.||02||Issue||05||Pages 2458-2462||May||ISSN 2348-9480 2015

Open access Journal International Journal of Emerging Trends in Science and Technology

Cascade Fuzzy Self Adaptive PID Controller for Inverse Response of Boiler Drum Level

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Abstract

In this paper, we are presenting new method with Cascade Fuzzy Self Adaptive PID Controller for Inverse response of the boiler drum water level. Conventional PID control System cannot reach a satisfactory result in Boiler drum water control system. Self tuning is that plant to be controlled often changes from time to time. This is especially true, if the plant is a unstable system with changing operation points then cascade fuzzy self adaptive PID provides effective method for adaptation of such changes. A cascade fuzzy self adaptive PID controller for boiler drum level control is proposed to improve time domain characteristics. In this paper, output of first fuzzy self adaptive controller is given to second self adaptive controller as a set point. From simulation, the performance of cascade self adaptive fuzzy PID controller is better than self adaptive fuzzy PID controller which improves time domain characteristics. MATLAB simulink tool is used to simulate cascade fuzzy self adaptive PID and self adaptive fuzzy PID control system.

Keywords: *Inverse Response, Self tuning PID, cascade self adaptive fuzzy PID Control.*

Introduction

Inverse Response (IR) behavior appears when the initial response of the output variable is in the opposite direction to the steady-state value. This behavior occurs in several systems in chemical process industry, such as distillation columns and drum boilers. Inverse response occurs when the process transfer function has an odd number of zeros in the open Right Half Plane (RHP). Drum level is one of the most important and critical control parameter for the boiler safety and stable operation. The inverse response is most challenging task for all control engineers.

The boiler operation is based on the demand of load in stem flow. Steam demand is depends on the downstream process via downstream equipment like turbine, Auxiliary steam for process etc. If the demand of steam increase or decreases then drum pressure will get affected due to sudden change in the load as well as steam drum level increase and decrease rapidly due to the change in pressure, it will change both density and boiling point of water in the circuit. As the process of increase and decrease in water level are usually called as swell and shrink reaction [1].

In this paper Fuzzy Self adaptive PID Controller & Cascade Fuzzy Self adaptive PID Controller is used for Inverse response f boiler drum level control. The self-adaptive fuzzy-PID is detecting deviation e(t) and the rate of deviation change Δe(t) continually, then use the method of fuzzy logic to modify PID controller's three parameters on-line according to the pre-determined fuzzy relationship of they, e(t) and Δe(t) [2].

Fuzzy control is a kind of intelligent control method, it doesn't require to establish the mathematical model of the object controlled, has faster response and smaller overshoot, is not sensitive to the changes of process parameters, and has robustness.

But fuzzy control is not preeminent as PID in control precision [3]. This Paper combines the classical PID control and cascade fuzzy control, gives the Cascade elf-adaptive fuzzy-PID control strategy and use it in the boiler drum water level control system.

Fuzzy self-adaptive PID Control

Although control theory has made great advance in the last few decades, which has led to many sophisticated control schemes, PID control still remains the most accepted type of control being used in industries today. The fact is that PID Controllers have simple structures and very well understood principal. Furthermore a well tuned PID controller can have excellent performance. The performance of a PID controller is crucially dependent on the tuning process.

The control objective during the “cold Start” is often different from the “normal operation” we often want a system to have a fast response time initially, but then put more emphasis on reducing steady state error. PID Control can be improved greatly if we will set parameters initially to ensure fast response time then tune the parameter to reduce steady state error. The second reason for self tuning is that plant to be controlled often changes from time to time. This is especially true if the plant is a nonlinear system with changing operation points. In this case, Cascade fuzzy self adaptive PID provides simple and effective method for adaptation of such changes [4].

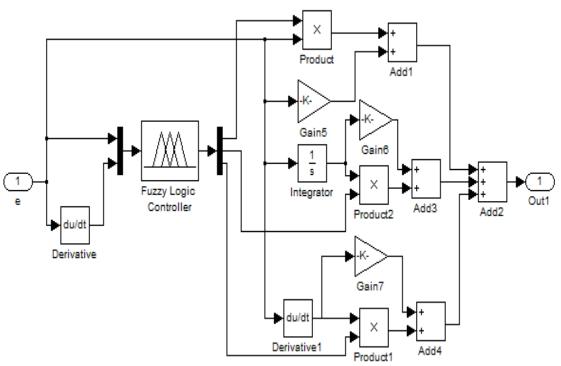
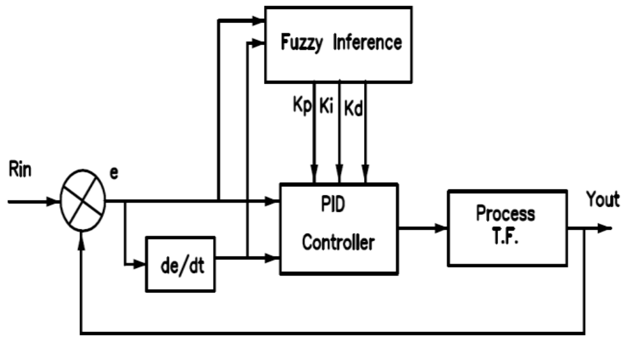


Figure: 1 Fuzzy Self Adaptive PID Block Diagram

Fuzzy self-adjusting PID controller is composed of adjustable PID controller and fuzzy controller. The core is fuzzy controller. It contains fuzzification, repository, fuzzy inference, Defuzzification, and input/output quantification and so on. Fuzzy logic is a rule which can map a space-input to another space-output. In engineering application, fuzzy logic has the following characters: 1) Fuzzy logic is flexible; 2) Fuzzy logic is based on natural language, and the requirement for intensive reading of data is not very high; 3) Fuzzy logic can take full advantage of expert information; 4) Fuzzy logic is easy to combine with traditional control technique [5,6].

Fuzzy self-adjusting PID controller takes E (the error between feedback value and desired value of controlled station) and Ec (error rate) as input. Using fuzzy reasoning method it adjusts the PID parameters (Kp, Ki, Kd) which can meet the requirements of E and Ec for PID parameter self-setting in different time. Change the PID parameters on line by using the fuzzy rules; these functions form the self-setting fuzzy PID controller. Its control system architecture is shown in figure 1.



.**Figure 2:** The structure of fuzzy self-adjusting PID controller

Cascade fuzzy self-adaptive PID

Load changes, which becomes apparent as changes in steam flow rate as drawn by the turbine, are feed forwarded to the boiler drum level controller as disturbance variables. The set point signal for the feed water flow control comes from the drum level controller. Feed water controller output then adjusts feed flow control valve to maintain drum level at the desired point. In accordance with the demand and characteristic of drum water level, choose the three-impulse control project as betrayed in figure 4. Where *aD*, *aW* and *aH* are conversion fractions of steam flux transducer, water-feeding flux transducer, differential pressure transducer [3].

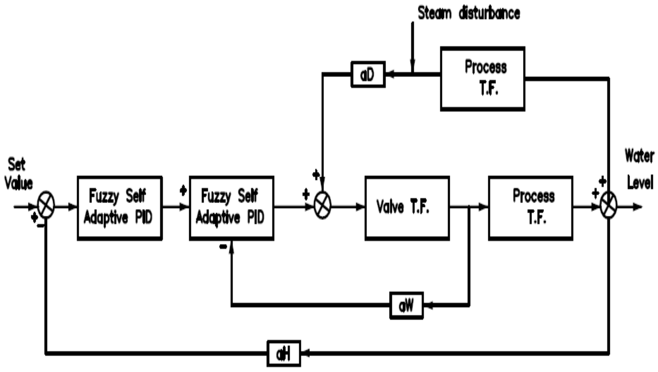


Figure: 3 Cascade Fuzzy Self Adaptive PID Block Diagram

According to the precision and control requirements, it is appropriate that 7 levels are usually selected. The Tables 2 to 4 is showing the fuzzy control rules of Kp. Ki, Kd and figure 3 to 5 showing the membership function curve for Error and change in error , and Kp, Ki, Kd. In accordance with demand and characteristic of drum water level, selected three impulse conversion fractions[7].

Table 1: Set of fuzzy rules for Kp.

Ec	E						
	NB	NM	NS	ZO	PS	PM	PB
NB	PB	PB	PM	PM	PS	ZO	ZO
NM	PB	PB	PM	PS	PS	ZO	NS
NS	PM	PM	PM	PS	ZO	NS	NS
ZO	PM	PM	PS	ZO	NS	NM	NM
PS	PS	PS	ZO	NS	NS	NM	NM
PM	PS	ZO	NS	NM	NM	NM	NB
PB	ZO	ZO	NM	NM	NM	NB	NB

Table. 2: Set of fuzzy rules for Ki.

Ec	E						
	NB	NM	NS	ZO	PS	PM	PB
NB	NB	NB	NM	NM	NS	ZO	ZO
NM	NB	NB	NM	NS	NS	ZO	ZO
NS	NB	NM	NS	NS	ZO	PS	PS
ZO	NM	NM	NS	ZO	PS	PM	PM
PS	NM	NS	ZO	PS	PS	PM	PB
PM	ZO	ZO	PS	PS	PM	PB	PB
PB	ZO	ZO	PS	PM	PM	PB	PB

Table 3: Set of fuzzy rules for Kd.

Ec	E						
	NB	NM	NS	ZO	PS	PM	PB
NB	PS	NS	NB	NB	NB	NM	PS
NM	PS	NS	NB	NM	NM	NS	ZO
NS	ZO	NS	NM	NM	NS	NS	ZO
ZO	ZO	NS	NS	NS	NS	NS	ZO
PS	ZO	ZO	ZO	ZO	ZO	ZO	ZO
PM	PB	NS	PS	PS	PS	PS	PB
PB	PB	PM	PM	PS	PS	PS	PB

The main controller directly controls the drum water level. Its output is the water flow. The establishment principle of fuzzy control rules: When the error is large, the error should be eliminated as quickly as possible. When the error is small, the overshoot should be prevented to maintain system stability. When the error change rate is negative, the water level has rising trend, if the error is negative at the time, the water supply flow should be reduced. When the error changes rate is positive, the water level has downward trend. If the error is positive at the time then the water supply flow should be increased. In other cases it depends. Control rules table is shown in TABLE 1 to 3 [8].

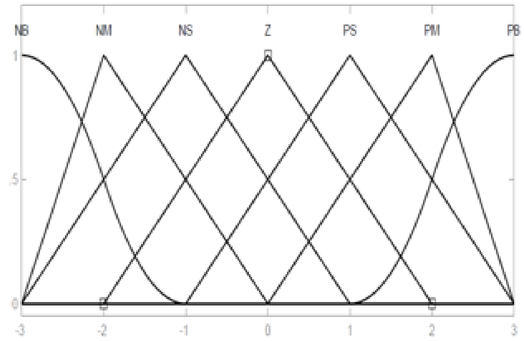


Figure 4: Membership function curve of Error (E), Change in Error (Ec)

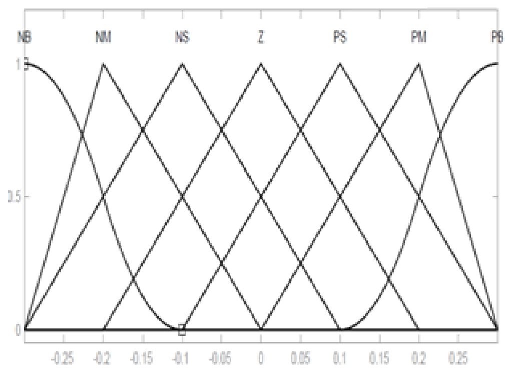


Figure 5: Membership function of Kp, Kd

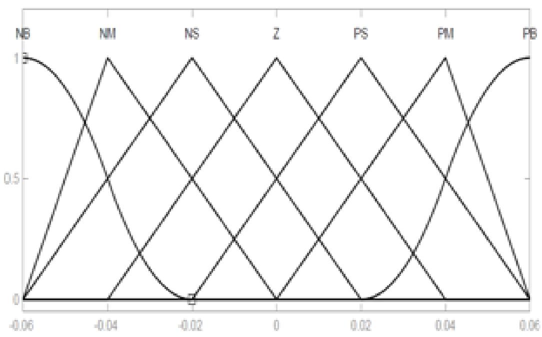


Fig. 6: Membership functions of Ki.

Result & Simulation

In this paper, we have considered following process transfer function, Valve Transfer function and disturbance. [9]

Process Transfer function

$$Gp(s) = \frac{-0.25S+0.25}{2S^2+S}$$

Valve Transfer Function

$$Gv(s) = \frac{1}{0.15S+1}$$

disturbance

$$Gd(s) = \frac{0.25S-0.25}{2S^2+S}$$

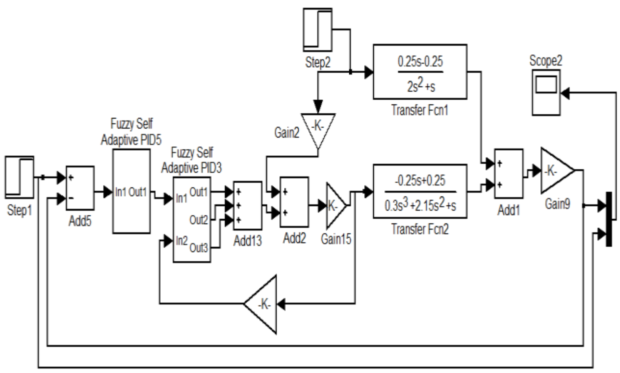


Figure: 7 Cascade Fuzzy Self Adaptive PID Controller MATLAB Simulink Model.

Using described simulink models for steam boiler drum level we get result of output response to a step response in drum level Fuzzy self adaptive controller & Cascade fuzzy self adaptive fuzzy controller with disturbances are shown in Fig. 7 and accordingly further Comparing Time domain specifications results are shown in Table : 4

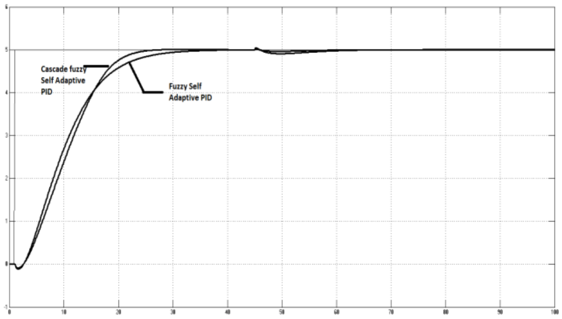


Fig. 8: Simulink result with disturbance.

Table 4: Comparing Time domain specifications with disturbances

Sr. No.	Time domain Specification	Fuzzy Self Adaptive PID	Cascade Fuzzy Self Adaptive PID
1	Rise Time	14.84	12.96
2	Settling Time	27.50	22.00
3	Overshoot	0.74	0.59
4	Undershoot	02.18	1.95

Conclusion

In this paper, Boiler drum level inverse response case study has been considered. From Simulink results and time domain specifications, it is observed that Cascade fuzzy self adaptive PID Controller gives better time domain specification compare to Fuzzy Self Adaptive PID. The simulation curves could be indicated the effectiveness of cascade fuzzy control strategy, which is based on fuzzy control theory and controls the drum water-level system of boiler.

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