Fuzzy Adapting PID Based Boiler Drum Water Level Controller

Periyasamy K[1]
[1]Assistant Professor
[1]Department of Electrical and Electronics Engineering
[1]E.S Engineering College, Villupuram, Tamil Nadu, India

Abstract--- The Boiler control is one of the most basic thermal power plant controls. Boiler water level control system includes steam drum water level, steam flow and water supply. The control objective is to control the water level of boiler drum. Fuzzy Adaptive PID controller is designed for controlling the boiler drum water level at a certain range. Fuzzy adaptive controller seeking the three parameters of PID controller and the relationship between e and e_c, make the best adjustment for PID parameters on the steam drum water level system automatically. MATLAB-SIMULINK models of the boiler drum water level system are developed for the PID, Fuzzy-PID, and Fuzzy Adaptive PID controller. The simulation result of Fuzzy Adaptive PID controller shows that the system is more stable, can meet the load and frequent fluctuations of water supply pressure, and improve the quality control of the internal and external disturbances.

Keywords: Boiler Drum Level, Proportional Integral–Derivative Controller (PID), Fuzzy Logic Control (FLC), Adaptive control, MATLAB.

I. INTRODUCTION

Boiler is important power equipment which is widely used in industrial production and daily life. Because of big change in load, frequently starting and stopping, it could not works safely for long-term and stability in economical operation mode through manual operation boiler [1]. Drum water-level control system is one of the most important part in boiler control system. Drum water-level is an important index to ensure the safety and stable operation for industrial boilers and the main controlled aim of automatic control system. Keeping water-level in a given range is important for enhancing steam quality, reducing wear and tear of equipment and operation cost. During the boiler running process, there are amounts of random interference factors, i.e. load impact, the distribution voltage wave and the variation of water supply, air supply and oil supply [2]. Even if the water supply flow and evaporation flow maintain a balance, the drum water-level is possible to change. In addition, instability phenomenon of fuel is subjected to the quality of the fuel. The drum water-level has complex dynamic properties [3],[4]. Currently, conventional PID control method is often used in most of the drum water-level control. But PID parameters are fixed. So we cannot adapt the PID parameters for the various disturbances.

II. BOILER DRUM WATER LEVEL CONTROL SYSTEM

A. System Structure

Three-element drum level control system adds a third variable, feed water flow rate, to manipulate the feed water control valve. This system basically cascades the summer output of the two element system to the feed water flow controller as a remote set point signal. This system provides close control during transient condition. The addition of the faster feed water secondary loop assures an immediate correction for feed water disturbances [5],[6]. The Block diagram of Boiler drum level control system has been shown in fig. 1.Where, G_1 (s) - transfer function between water supply and drum water level, G_2 (s) - transfer function between steam flow and drum water level, a_W - conversion co-efficient of water supply transmitter, a_S - conversion co-efficient of steam flow transmitter, a_H - conversion co-efficient of water level transmitter.

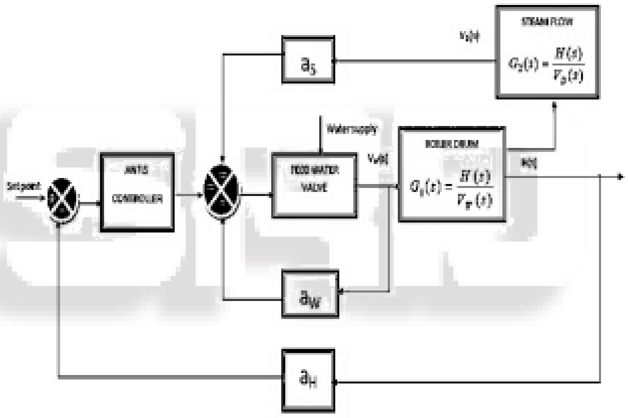

Fig.1: Block diagram of Boiler drum level control system.

B. Mathematical Model

The drum level has many influence factors on water level control, such as feed water flow, steam flow, steam pressure, boiler pressure, drum temperature, where the variations of steam flow and feed water flow are the main factors of affecting the stabilized level. This paper only considers the main influence factors, which only considers the steam flow and feed water flow variations. According to the drum material balance, drum water level dynamic balance equation is

$$F(t) = Q_W(t) - Q_D(t) \tag{2.1}$$

Where $Q_w(t)$ and $Q_D(t)$ are feed water flow and steam flow respectively. F(t) is drum water level variation. The influence of the drum water level caused by water flow disturbance transfer function between water flow and drum water level is

$$G_1(s) = \frac{H(s)}{V_W(s)} = \frac{K_W}{T_1 S(T_2 S + 1)} \tag{2.2}$$

The influence of the drum water level caused by the steam flow, the transfer function between the steam flow and drum water level is

$$G_2(s) = \frac{H(s)}{V_D(s)} = -\frac{T_D S + K_D}{T_1 S(T_2 S + 1)} \tag{2.3}$$

Let assume that for the control valve of the system, the response is that of a first order system,

$$\frac{V_W(s)}{C(s)} = \frac{K_V}{\tau_V S + 1} \tag{2.4}$$

Where, C(s) is controller output, $V_W(s)$ is control value output.

III. DESIGN OF FUZZY ADAPTIVE PID CONTROLLER

A. Fuzzy Adaptive PID

The block diagram of Fuzzy Adaptive PID controller has been shown in fig. 2.

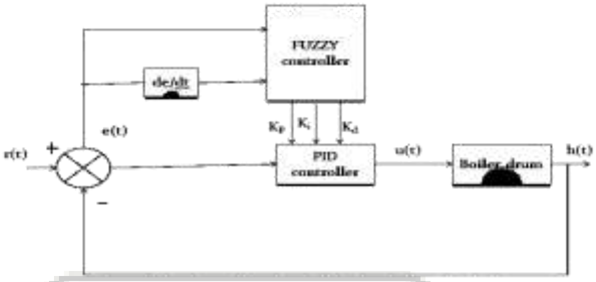

Fig. 2: Block diagram of Fuzzy Adaptive PID controller

The fuzzy adaptive PID controller consists of two parts, one is a conventional PID controller and another is a fuzzy reasoning controller. The deviation e and the error rate of the deviation e_c (de/dt) are used as the input. The controller has self-adapting function, and can adjust control parameters according to the fuzzy control rules, so can meet the control requirements for different e and e_c. In this controller, the main idea for the PID parameters adjustment is to find the fuzzy relations among three Parameters K_p, K_i, K_d, of conventional PID controller, absolute value of an error *e* and absolute value of error rate.

In practice, with continual testing, three controller parameters are modified on-line to meet the different requirements and also get a good stable performance based on the fuzzy control rules for different e and e_c.

B. Fuzzy Logic Controller design

The fuzzy controller has two-input and three-output system. Block diagram of fuzzy controller for two-input and three-output has been shown in fig. 3. The mamdani type FIS editor for two-input and three-output system has been shown in fig. 4.

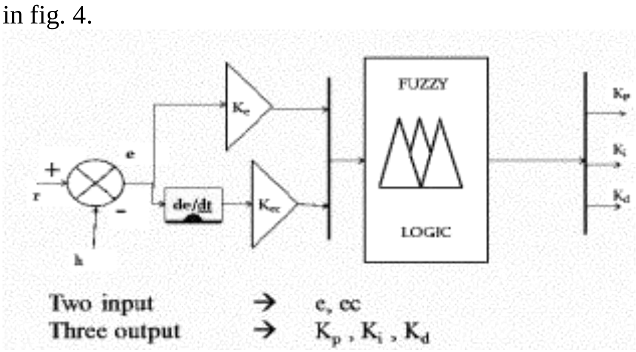

Fig. 3: Block diagram of fuzzy controller for two-input and three-output

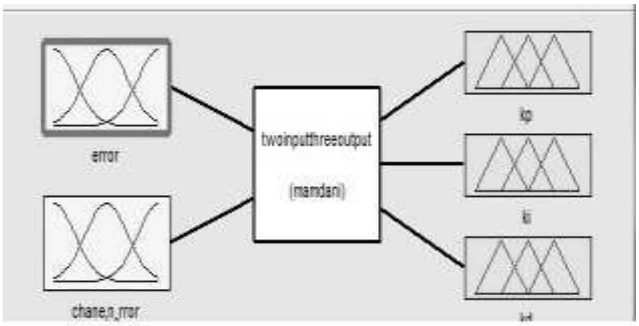

Fig. 4: The mamdani type FIS editor for two-input and three-output system

C. Membership Function

The linguistic variables chosen for this controller are speed deviation, active power deviation and voltage..

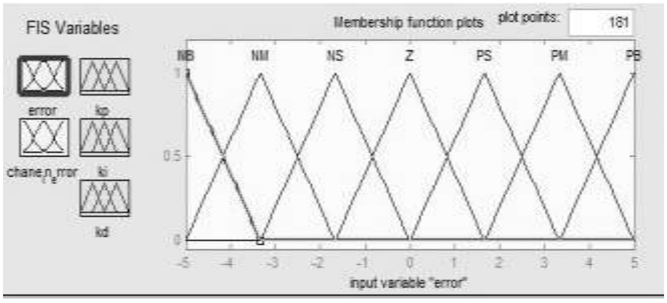

Fig. 5: Membership function for Input variable "error"

In this, the speed deviation and active power deviation are the input linguistic variables and voltage is the output linguistic variable. Each of the input and output fuzzy variables is assigned seven linguistic fuzzy subsets varying from negative big (NB) to positive big (PB). Each subset is associated with a triangular membership function to form a set of seven membership functions for each fuzzy variable.

Fig.5 and fig.6 shows Membership function for Input variable error and change in error. Fig. 7, fig.8 and fig.9 show Membership function for output variable K_p, K_i and K_d

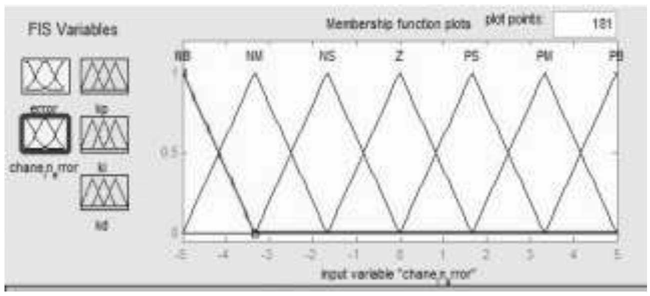

Fig. 6: Membership function for Input variable "change in error"

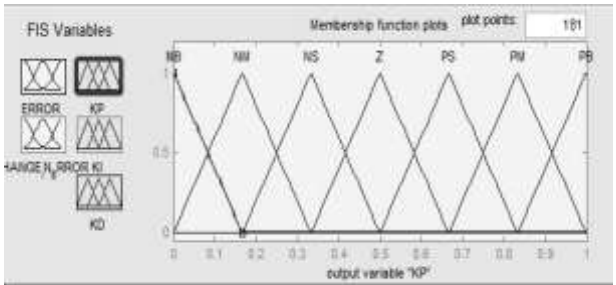

Fig. 7: Membership function for output variable "K_p"

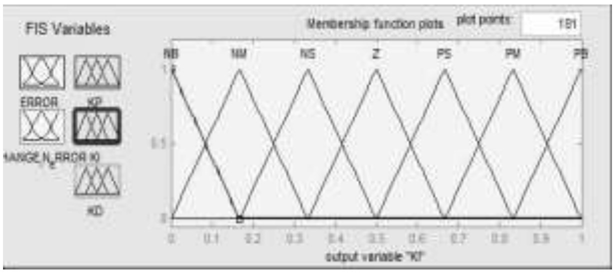

Fig. 8: Membership function for output variable "K_i"

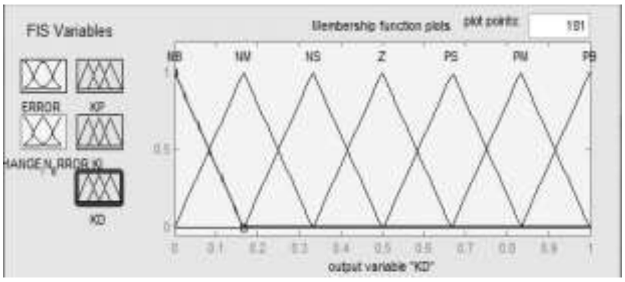

Fig. 9: Membership function for output variable "K_d"

D. *Fuzzy rule base*

The linguistic terms chosen for this controller are seven. They are negative big (NB), negative medium (NM), negative small (NS), zero (Z), positive small (PS), positive medium (PM) and positive big (PB). After assigning the input, output ranges to define fuzzy sets, mapping each of the possible seven input fuzzy values of speed deviation, active power deviation to the seven output fuzzy values is done through a rule base. Thus the fuzzy associative memory (FAM) comes into picture. The rules are framed keeping in mind the nature of the system performance and common sense.

E_c / E	NB	NM	NS	Z	PS	PM	PB
NB	PB	PB	PM	PM	PS	Z	Z
NM	PB	PB	PM	PS	PS	Z	NS
NS	PM	PM	PM	PS	Z	Ns	Ns
Z	PM	PM	PS	Z	NS	NM	NM
PS	PS	PS	Z	NS	NS	NM	NM
PM	PS	Z	NS	NM	NM	NM	NB
PB	Z	Z	NM	NM	NM	NB	NB

Table 1: FAM table for K_p

E_c / E	NB	NM	NS	Z	PS	PM	PB
NB	NB	NB	NM	NM	NS	Z	Z
NM	NB	NB	NM	NS	NS	Z	Z
NS	NB	NM	NS	NS	Z	PS	PS
Z	NM	NM	NS	Z	PS	PM	PM
PS	NS	NS	Z	PS	PS	PM	PB
PM	Z	Z	PS	PS	PM	PB	PB
PB	Z	Z	PS	PM	PM	PB	PB

Table 2: FAM table for K_i

E_c / E	NB	NM	NS	Z	PS	PM	PB
NB	PS	NS	NB	NB	NB	NM	PS
NM	PS	NS	NB	NM	NM	NS	Z
NS	Z	NS	NM	NM	NS	NS	Z
Z	Z	NS	NS	NS	NS	NS	Z
PS	Z	Z	Z	Z	Z	Z	Z
PM	PB	NS	PS	PS	PS	PS	PB
PB	PB	PM	PM	PM	PS	PS	PB

Table 3: FAM table for K_d

Table 1, 2 and 3 shows the FAM rules for K_p, K_i and K_d.

IV. SIMULATION MODEL AND RESULTS

The boiler's steam-providing *flux* is 120 t/h, the transfer function of water-feeding and water level is

$$G_1(s) = \frac{H(s)}{V_W(s)} = \frac{0.034}{S(29S+1)}[mm*(t/h)^{-1}] \qquad (4.1)$$

The transfer function of steam and water level is,

$$G_2(s) = \frac{h(s)}{D(s)} = \frac{3.5}{14S+1} - \frac{0.034}{S}[mm*(t/h)^{-1}] \qquad (4.2)$$

Let assume that for the control valve of the system, the response is that of a first order system,

$$\frac{V_W(s)}{C(s)} = \frac{1}{29S+1} \qquad (4.3)$$

Where, C(s) is controller output, $V_W(s)$ is control value output. $K_{V\ is}$ valve time constant = 1, τ_v=29S

Water supply flow transmitter coefficient (a_W) is when the water supply changes from 0 to 120t/h. The input voltage is 0~10V. So,

$$a_W = \frac{10}{120} = 0.083[V*(t/h)^{-1}] \qquad (4.4)$$

Steam out flow transmitter coefficient (a_S) is when the steam load changes from 0 to maximum flow 120t/h. The output voltage is also 0 ~ 10V. So,

$$a_S = \frac{10}{120} = 0.083[V*(t/h)^{-1}] \qquad (4.5)$$

Water level transmitter coefficient (a_H) is at the maximum water level fluctuation range of ±150mm. The transmitter output voltage is 0 ~ 10V. So,

$$a_H = \frac{10}{300} = 0.0333(V/mm) \qquad (4.6)$$

Simulation model for Fuzzy Adaptive PID controller has been shown in fig.10.

Based on the control theory of Adaptive fuzzy PID and drum water level control system structure described above use the Simulink in MATLAB to do simulation; the model is given in figure 5. The control step setting value is R(t)=50u(t), in controller, the proportion factor is Kp=6, the integral factor is Ki=0.1, the differential factor is Kd=0, the quantification factor in fuzzy controller is Ke=6, Kec=120, the proportion factor of fuzzy output is Ku=0.833, simulation time is 1000s. From the result of simulation, we can see, in contrast with traditional PID control, Adaptive fuzzy PID control has shorter response time and smaller overshoot; it has stronger restraining ability against external interaction, so it acquires the good effect in control to false water level.

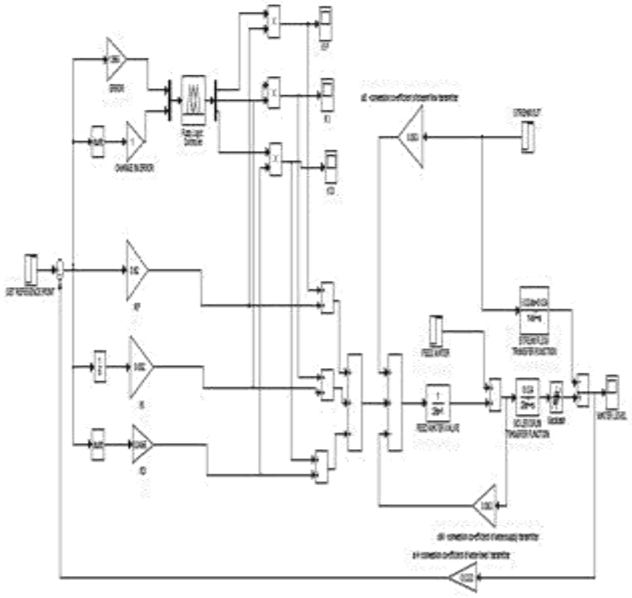

Fig. 10: Simulation model for Fuzzy Adaptive PID controller.

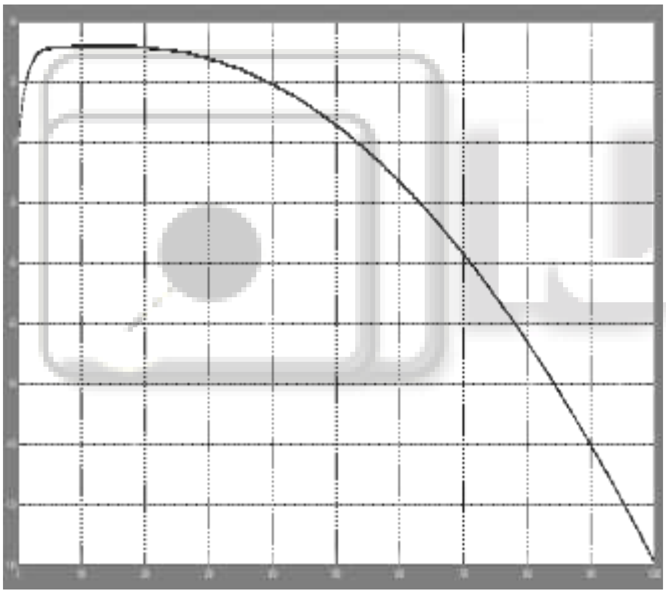

Fig. 11: Simulation output for PID controller

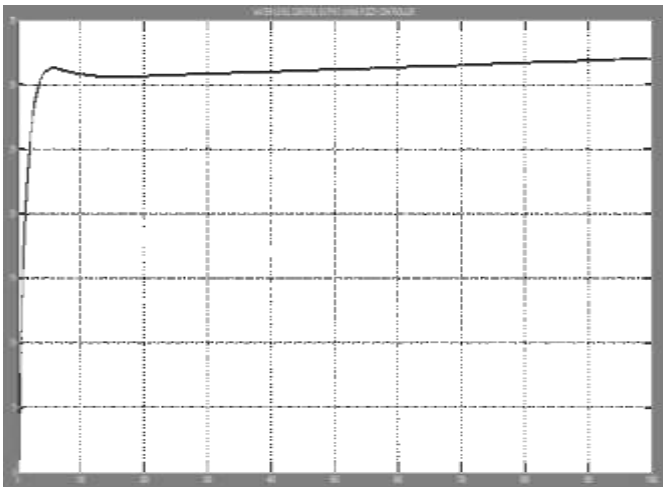

Fig. 12: Simulation output for Fuzzy controller

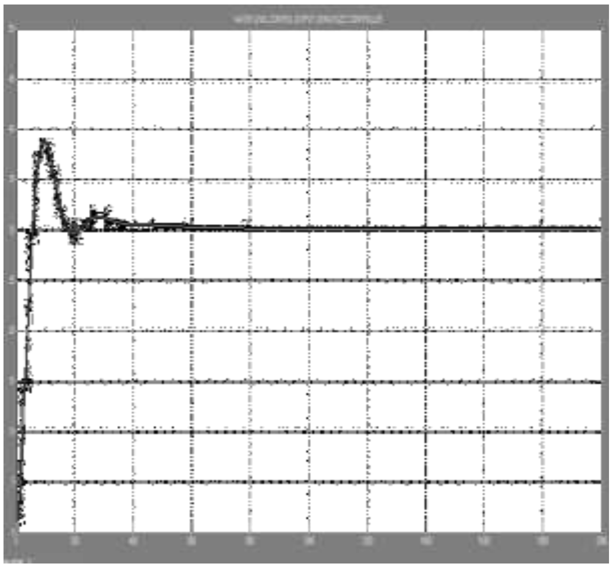

Fig. 13: Simulation output for Fuzzy - PID controller

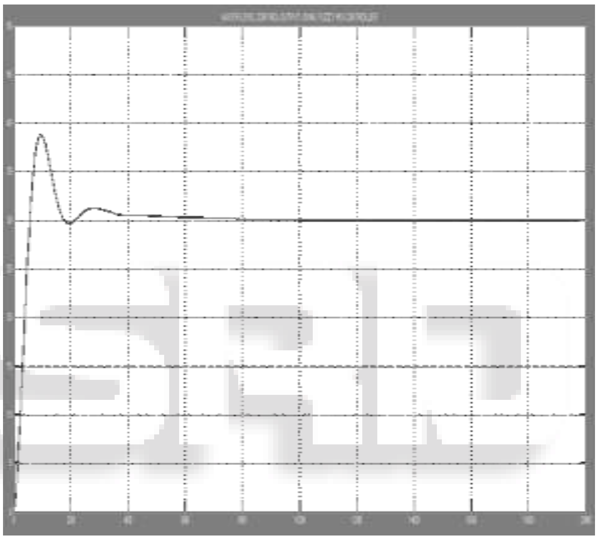

Fig. 14: Simulation output for Fuzzy Adaptive PID controller

Fig. 11 shows the response of PID controller for boiler drum water level system. The output response of PID controller is unstable. The fig .12 shows the simulation output of Fuzzy controller boiler drum water level system. The Simulation output of Fuzzy-PID and Fuzzy Adaptive PID controller for boiler drum water level system has been shown in fig.13 and fig.14.

V. CONCLUSION

In this paper fuzzy adaptive PID controller is designed, it is based on the Fuzzy Inference System. To overcome the awkward task of choosing membership function of fuzzy controller. So fuzzy adaptive PID can adjust fuzzy rule and MF. Water level is a complex control objective in boiler drum; we use fuzzy adaptive PID to control the water level on the computer. From the simulation, fuzzy adaptive PID control effect is better than fuzzy controller or general cascade PID controller.

REFERENCES

[1] Hulinjing, Zhangke, Liutao, "Study on the Boiler

Drum Water Level Based on Fuzzy Adaptive Control", 24th Chinese Control and Decision Conference (CCDC) 2012 IEEE p.1659-1663.

[2] L,Chen, C. Wang, Y.Yu, Y. Zhao," The research on boiler drum water level control system based on self-adaptive fuzzy-PID", 2010 IEEE p.1582- 1584.

[3] V. Wei-jie, L. Yong-xin, "Boiler Drum Level controlled by Fuzzy Self-adapting PID", Second Asia-Pacific Conference on Computational Intelligence and Industrial Applications, 2009 IEEE PACIIA p.381-384.

[4] Z. Haihe,W. YU, "Fuzzy Controller of Drum Water Level for Industrial Boile", International Conference on Computer, Mechatronics, Control and Electronic Engineering (CMCE) 978-1-4244-7956-6/1 0 IEEE 2010 p.400-403.

[5] Z. Wang, Q. Wang," Application of Fuzzy Controller in Drum Water-level Control", International Conference on Mechatronic Science, Electric Engineering and Computer August 19-22, 2011, 978-1-61284-722 © IEEE p. 174- 176.

[6] J. Wang, Q.Meng," Research on Optimal Control System of Boiler Drum Water Level Based on LQR", 978-1-4577-1701-7/11©2011 IEEE p.1092- 1094.