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Boiler Tank Level Control Using Fuzzy Logic

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Abstract: In control systems there are a number of generic systems and methods which are encountered in all areas of industry and technology. From the dozens of ways to control any system, it turns out that fuzzy is often the very best way. The only reasons are faster and cheaper. The purpose of this project is to design a simulation system of fuzzy logic controller for water tank level control by using simulation package which is Fuzzy Logic Toolbox in MATLAB software.** This paper proposes use of fuzzy techniques in Drum Level Control. **A nonlinear coordinated control concept is presented in order to improve the flexibility and the performance of a once-through power plant. In order to find the best design to stabilize the water level in the system, some factors will be considered. For this project, the water level was controlled by using three rules of membership function. This project was focused to the software part only. By doing some modification of this project, the design will be very useful for the control of thermal power plant.Due to the dynamic behavior of power plant, controlling the Drum Level is critical. If the level becomes too low, the boiler can run dry resulting in mechanical damage of the drum and boiler tubes. If the level becomes too high, water can be carried over into the Steam Turbine which shall result in catastrophic damage. Therefore an fuzzy based system is proposed to replace the existing conventional controllers. By doing some modification of this project, the design will be very useful for the control of thermal power plant.

Keywords
Fuzzy Logic control, Boiler Drum Level Control, Level Control, Thermal Power plant

I. INTRODUCTION

The Private owned Power station in India that has been considered in this paper is a Coal fired 660 MW Power Station. The overview of a 660 MW unit is shown in figure 1. The Drum level control strategies are reviewed for a 660 MW Boiler using fuzzy logic. In the first strategy the PID controller gains are varied based on fuzzy logic rules. Fuzzy rules are utilized on-line to determine the controller parameters based on tracking error and its first time derivative. In the second strategy the Drum level set point is varied based on fuzzy logic rules. Simulation and experimental results of the proposed schemes show good performances of fuzzy based strategies in terms of dynamic and steady state characteristics of all loops. Simulations are performed using MATLAB/SIMULINK.

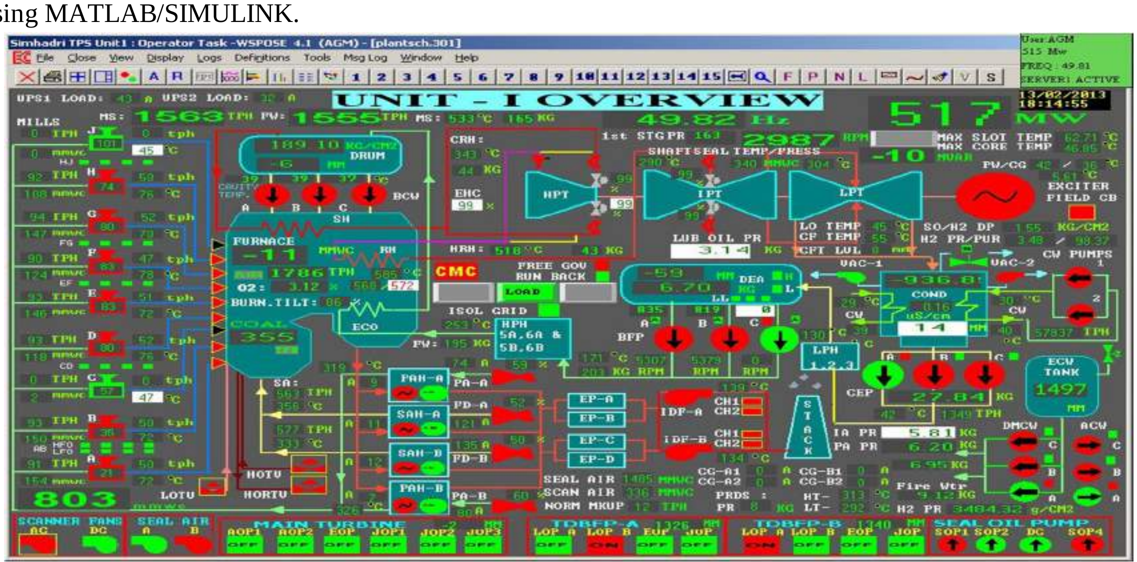

Fig. 1 Overview of a 660 MW unit

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II. DRUM LEVEL CONTROL

The boiler drum is where water and steam are separated. The general layout of a 660 MW Drum level control loop is shown in Figure 2.

The 3 element drum level control is shown in figure 3. The elements correspond to the three variables that are used as indices of control variables: drum liquid level, feed-water flow, and steam flow. The drum level controller maintains a constant drum level using the flow demand as a set point and uses the drum level process variable as a feedback signal.

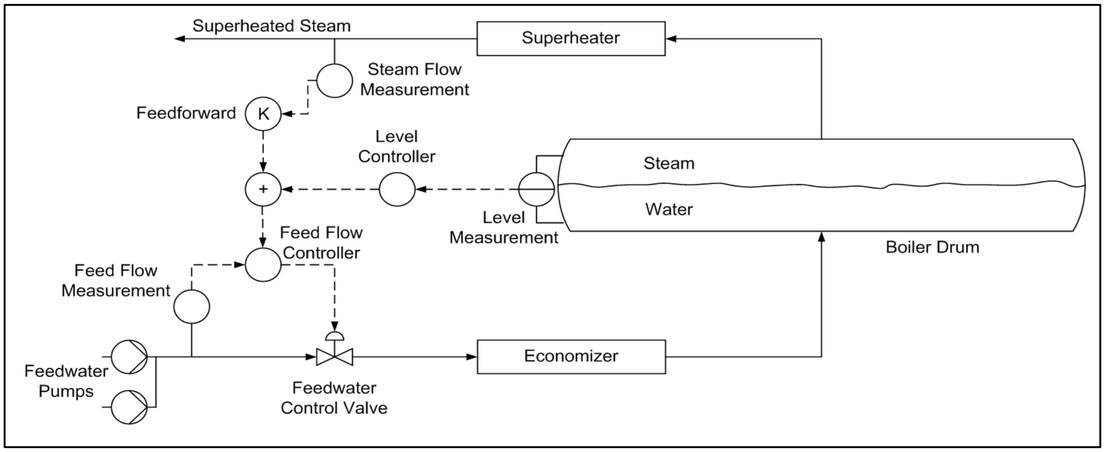

Fig. 2 660 MW Drum Level control loop

The Drum level is derived from the following equation:

$h = DP + H(\gamma r - \gamma s) + (\gamma w - \gamma s)$

where:

h = True drum level – Inches

DP = Measured DP head – Inches

H = Distance between taps – Inches

γs = Steam Specific Gravity (S.G.)

γr = Reference leg (S.G.)

γw = Drum Water (S.G.)

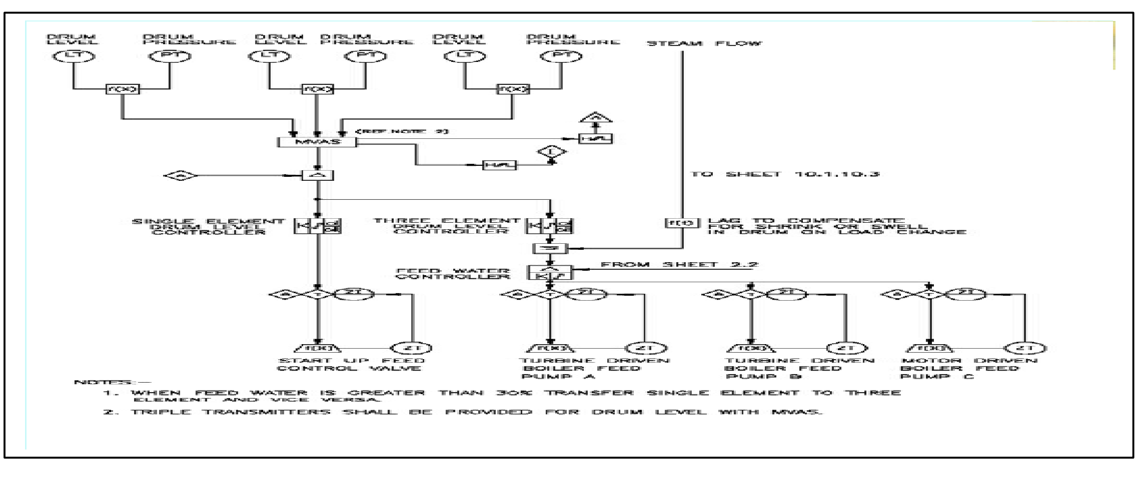

Fig. 3 3-Element Drum Level control loop

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PID controller constants obtained during performance guarantee tests done by DCS (Distributed Control System) supplier normally hold good for all times. However due to aging of the plant or due to special operating situations (FGMO- Free governing Mode operation, high fluctuations in coal quality , fuel switching, different load conditions etc.) there is a need for changing the PID parameters. Hence a new method is to be devised to change the PID controller parameters. The fuzzy logic controller (FLC) proposed here is intended to show the flexibility, adequacy and reliability of the boiler operation while using the fuzzy logic control action. Fuzzy gain scheduling is considered to be the most promising alternative combining fuzzy logic with conventional controllers. A rule based scheme for gain scheduling of PID controllers for drum level control is designed in this paper. The new scheme utilizes fuzzy rules and reasoning to determine the controller parameters and the PID controller generates the control signal. The Fuzzy Gain Scheduler proposed in this paper can also be applied to any control loop in the plant, which consists of a PID controller. Fuzzy PID tuning is no longer a pure knowledge or expert based process and thus has potential to be more convenient to implement. The approach taken here is to exploit fuzzy rules and reasoning to generate controller parameters. For the proposed study, Fuzzy inference engine is selected and the centroid method is used in defuzzification process.[5,6,7]

The PID controller parameters (K p, Ki, Kd) are determined based on the current error e (t) and its derivate Δ e (t) . Proportional controller has the effect of increasing the loop gain to make the system less sensitive to load disturbances, the integral error is used principally to eliminate steady state errors and the derivative action helps to improve closed loop stability. The parameters Kp, Ki and Kd are thus chosen to meet prescribed performance criteria, classically specified in terms of rise and settling times, overshoot and steady state error, following a step change in the demand signal.

The fuzzy adapter adjusts the PID parameters to operating conditions, in this case based on the error and its first difference, which characterizes its first time derivative, during process control. The structure of the fuzzy gain scheduler is illustrated in figure. 4

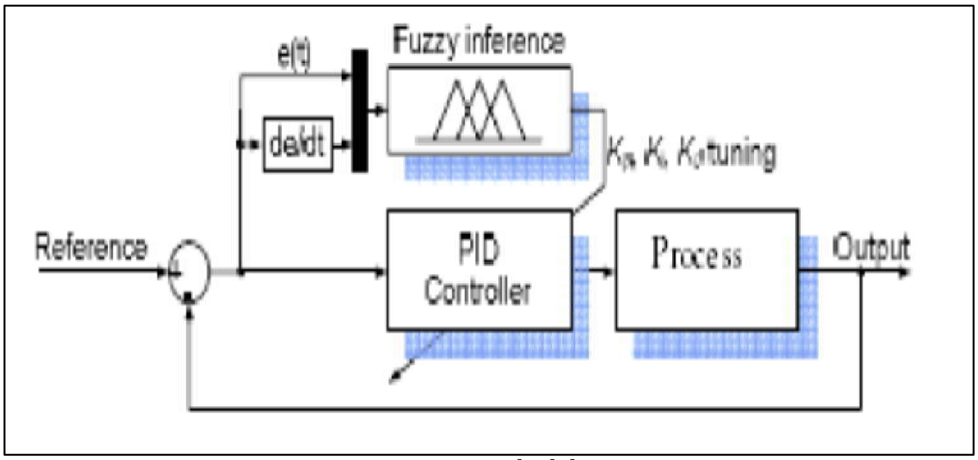

Fig. 4 Fuzzy Gain Scheduler Structure

The Fuzzy Gain Controller of Drum level control loop has 2 inputs (error e and derivative of error de) and three outputs Kp, Ki and Kd. Domain of e is (-9,9), de is (-6,6) and the fuzzy set of e and de are NB (Negative Big), NM (Negative Medium), NS (Negative Small), ZE (Zero), PS (Positive Small), PM (Positive Medium), PB (Positive Big).

Domain of Kp is {0, 200}, Ki is {0, 8} and Kd is {0, 40} and the fuzzy set of Kp, Ki,Kd is { NB (Negative Big) NM (negative Medium), NS (Negative Small), ZE (Zero), PS (Positive Small), PM(Positive medium), PB (Positive Big)}. The fuzzy sets are all triangular MF.

When e is large , in order to the system to enable the system to fast track, a large Kp and a small Kd is selected. In order to prevent the system overshoot to be too large, the integral term is limited. When e is in the medium value , in order to make the system have a smaller overshoot, Kp is made smaller. In this case Kd impacts on the system response than the other factors . When e is small, in order to make the system has good steady-state performance; Kp and Ki are made larger. Meanwhile, in order to avoid the system oscillating near the set value , the selection of Kd is critical. Taking into account the interaction between the three parameters and the analysis, the control rules are established for Kp, Ki, and Kd as shown in Table 1 to 5

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Table-1 Fuzzy tuning rules for Kp Change in error e

Change in derivative error de	NB	NM	NS	ZO	PS	PM	PB
NB	PS	ZO	NS	NB	NS	ZO	PS
NM	PB	PS	ZO	NS	ZO	PS	PB
NS	PB	PB	PS	ZO	PS	PB	PB
ZO	PB	PB	PB	PS	PB	PB	PB
PS	PB	PB	PS	ZO	PS	PB	PB
PM	PB	PS	ZO	NS	ZO	PS	PB
PB	PS	ZO	NS	NB	NS	ZO	PS

Table-2 Fuzzy tuning rules for Ki Change in error e

hange in derivative error de	NB	NM	NS	ZO	PS	PM	PB
NB	NB	NB	NS	ZO	NS	NB	NB
NM	NB	NS	ZO	PS	ZO	NS	NB
NS	NS	ZO	PS	PB	PS	ZO	NS
ZO	NS	PS	PB	PB	PB	PS	NS
PS	NS	ZO	PS	PB	PS	ZO	NS
PM	NB	NS	ZO	PS	ZO	NS	NB
PB	NB	NB	NS	ZO	NS	NB	NB

Table-3 Fuzzy tuning rules for Kd Change in error e

Change in de	NB	NM	NS	ZO	PS	PM	PB
NL	ZO	PS	PB	PB	PB	PS	ZO
NM	NS	ZO	PS	PB	PS	ZO	NS
NS	NB	NS	ZO	PS	ZO	NS	NB
ZO	NB	NS	ZO	PS	ZO	NS	NB
PS	NB	NS	ZO	PS	ZO	NS	NB
PM	NS	ZO	PS	PB	PS	ZO	NS
PL	ZO	PS	PB	PB	PB	PS	ZO

Table-4 49 Fuzzy rules

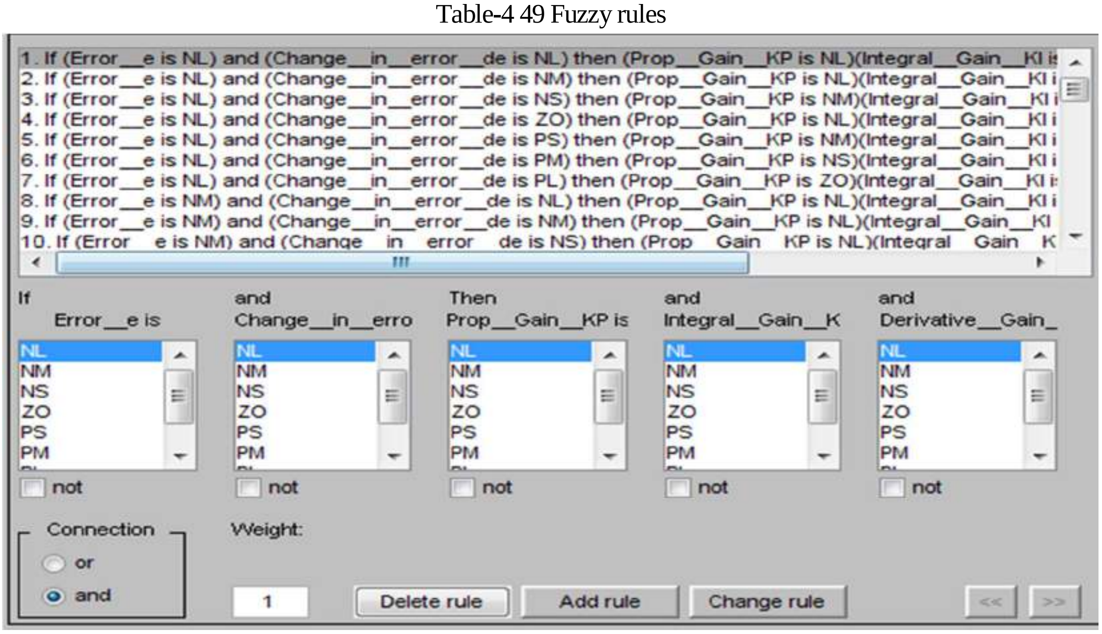

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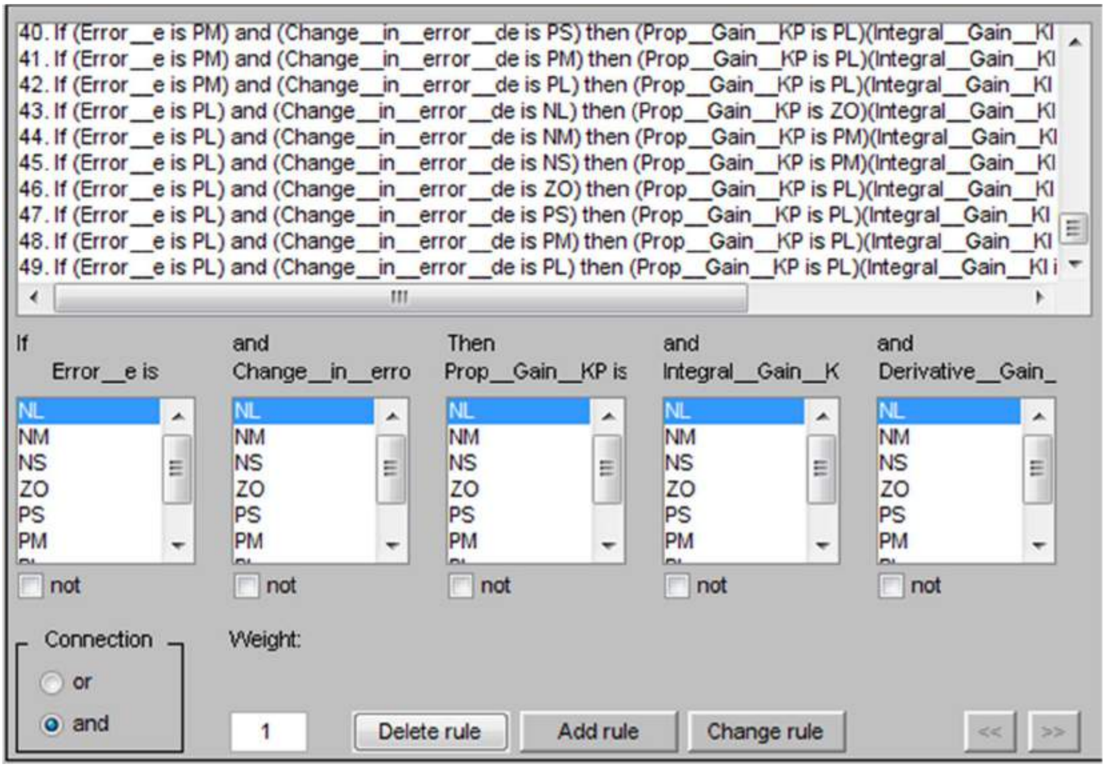
Table-5 49 Fuzzy rules



The configuration of the Fuzzy PID control block in MATLAB is shown in Figure 5.

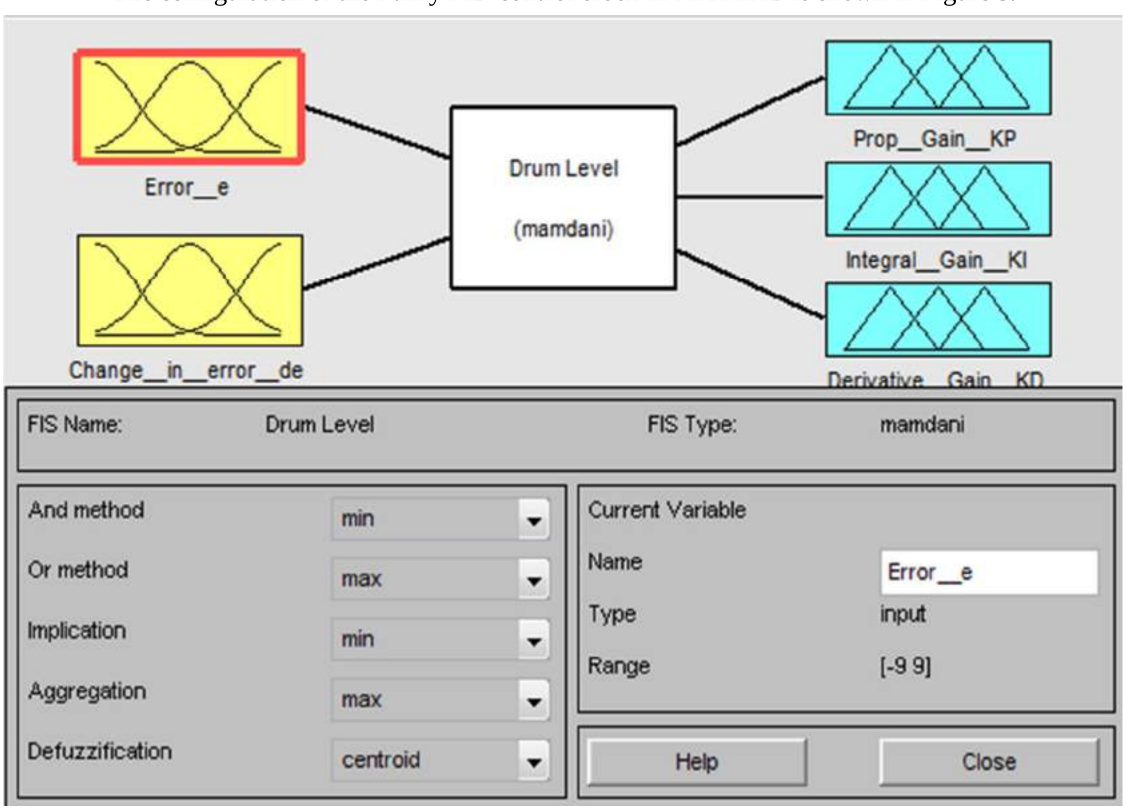


Fig 5. Fuzzy PID configuration

The surface view of various input combinations and Output is shown in Figure 6.

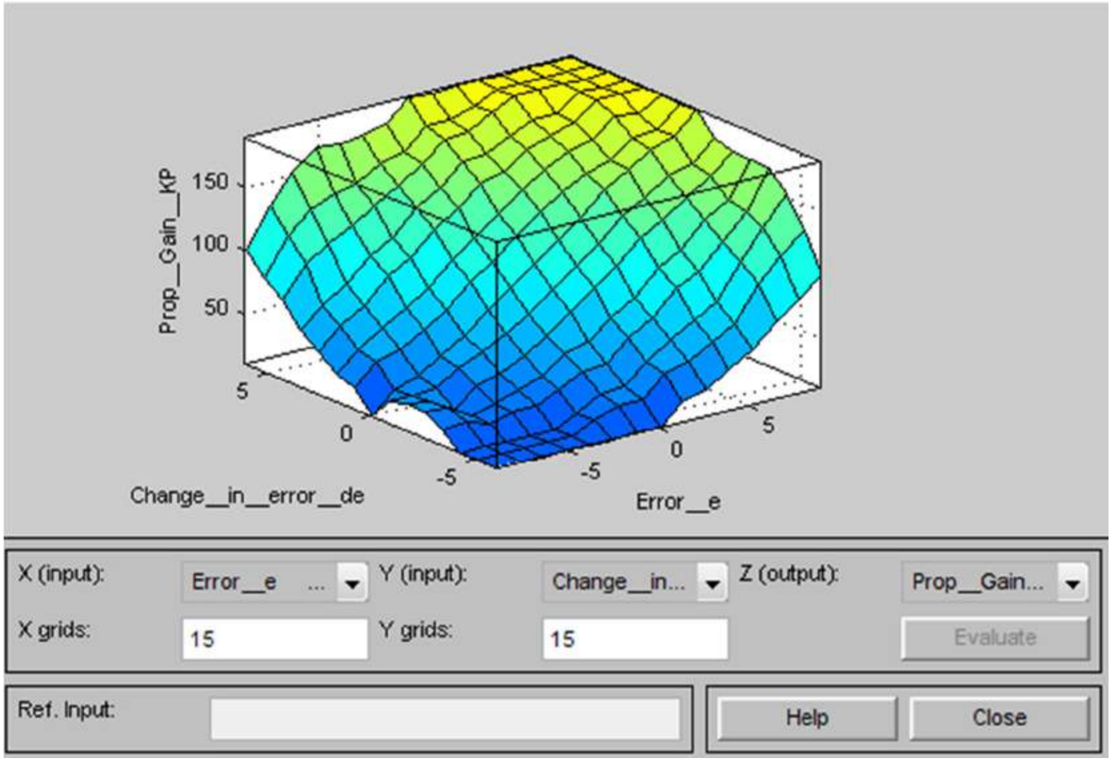


Fig 6. Fuzzy PID configuration

III. CONCLUSION

The purpose of this paper is to demonstrate the fuzzy techniques in a Power Station. The application of fuzzy logic to design the fuzzy logic controller for Drum Level control yields a practical solution that makes use of operation staff's experience and allows independent adjustment of controller parameters to control response. Results of simulation experiments demonstrate that the fuzzy logic algorithm may improve the performance of Drum Level control loop well beyond that obtained in conventional PID algorithm. Hence, the fuzzy logic proposed approach makes it possible to easily build high-performance tailor-made controllers for any specific control loop in the Power Plant thereby optimizing power plant efficiency and cost.

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