Designing Fuzzy Controller for Second Order System

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Abstract— As a practical approach, it is more difficult to set the controller gains compared to proportional-integral-derivative (PID) controllers due to the nonlinearity of the fuzzy controllers. This research paper proposes a design procedure and a tuning procedure consisting of tuning rules from the PID domain over to fuzzy single-loop controllers. The idea is to replace conventional PID controller with an equivalent linear fuzzy controller and eventually fine-tune the nonlinear fuzzy controller. This is relevant whenever a PID controller is possible or already implemented.
Key words: PID, Fuzzy, Controllers

I. Introduction

Fuzzy logic has become a prime tool for a large applications extending to artificial intelligence. The fuzzy systems convert these rules to their mathematical equivalents where its logic is built on a set of user- supplied human language rules. This results in much more accurate representations of the way systems behave in the real world. [4]

Fuzzy PID controllers are used as controllers instead of linear PID controller in all conventional or modern control system applications. They change the error between the measured or controlled variable and the reference variable, into a command, which is applied to the actuator of a process.

Fuzzy logic is simple and flexible. It can handle problems with imprecise and incomplete data, and it can model nonlinear functions of arbitrary complexity. [5]

II. Various Fuzzy Controller [1]

A. Fuzzy P Controller

The FP controller has two tuning gains *GE* and *GU*, where the crisp proportional controller has just one, *Kp*.

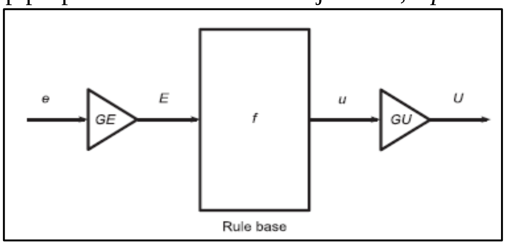

Fig. 1: Fuzzy P Controller

B. Fuzzy PD Controller

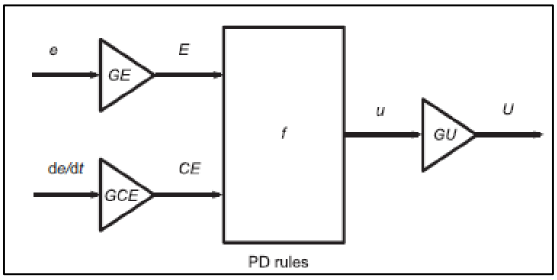

Fig. 2: Fuzzy PD Controller

The fuzzy PD controller may be applied when proportional control is inadequate. The derivative term reduces overshoot, but it may be sensitive to noise as well as abrupt changes of the reference causing derivative kick.

C. Fuzzy PD+I Controller

The integral action is necessary when the closed-loop system exhibits a sustained error in steady state . The integral action will increase (decrease) the control signal if there is a positive (negative) error, even for small magnitudes of the error.

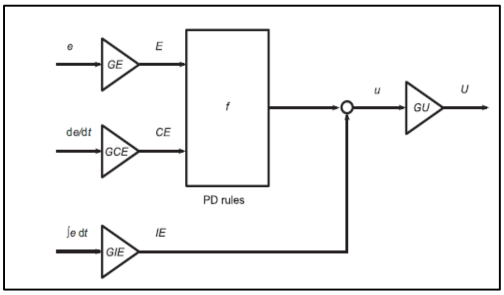

Fig. 3: Fuzzy PD+I Controller

D. Fuzzy Incremental Controller

The fuzzy incremental (FInc) controller in Figure 4 is of almost the same configuration as the FPD controller, except for the added integrator

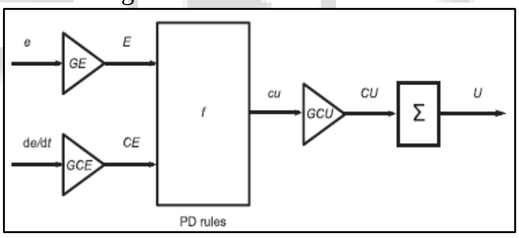

Fig. 4: Fuzzy Incremental Controller

III. Fuzzy Controller Design Procedure

- Start building and tuning a conventional PID controller
- Replace it with an equivalent linear fuzzy controller.
- Make the fuzzy controller nonlinear.
- Fine-tune it.

IV. Tuning the PID Controller

The PID controller for normal closed loop operation is tuned by the Ziegler-Nichols closed loop tuning for frequency response of the system, and the P-I-D parameters were set according to the following table:[1]

Here, Ku is the amplitude of the critical oscillations and Tu is the period of the critical oscillations.

Controller	P	I	D
P	0.5Ku	----------	--------
PI	0.45Ku	0.833Tu	--------
PID	0.6Ku	0.5Tu	0.125Tu

Table 1: PID controller table [2]

V. RELATIONSHIPS BETWEEN LINEAR FUZZY AND PID GAINS

	Kp	1/Ti	Td
FP	GE ∗ GU		
FInc	GCE ∗ GCU	GE/GCE	
FPD	GE ∗ GU	—	GCE/GE
FPD+I	GE ∗ GU	GIE/GE	GCE/GE

Table 2: PID and fuzzy gains [1]

Where GE GU GCE and GCU are gains of fuzzy controllers

VI. LINEAR FUZZY CONTROLLER TO NONLINEAR CONTROLLER

The third step in the overall design procedure is to make the fuzzy controller nonlinear. The control surface is the only component which governs the nonlinear behaviour of the controller, affecting the dynamics of the closed-loop system [2]

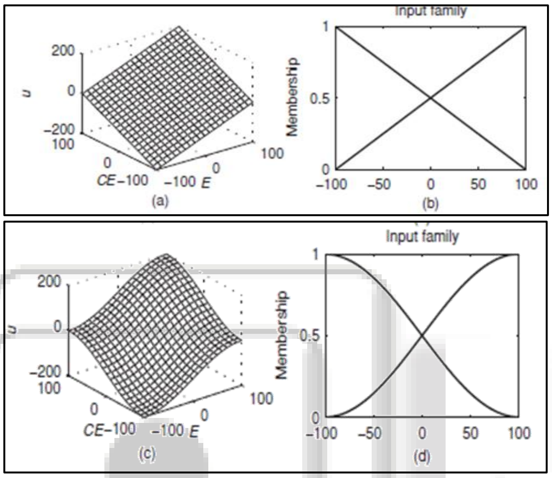

Fig. 5: Surface of linear and non linear fuzzy controller

VII. FINE TUNING

Creating the membership functions "narrow" near the ZE region and "wider" far from the ZE region can improve the controller's resolution in the proximity of the desired response when the system output is close to the reference values, thus improving the tracking performance.[3]

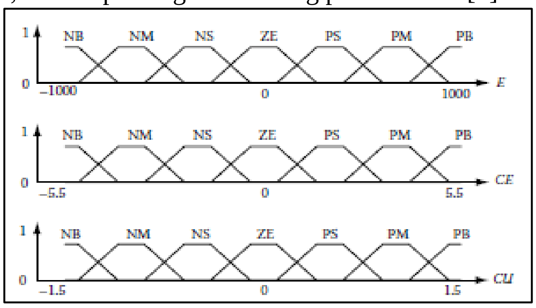

Fig. 6: Member Ship Before Tunning.

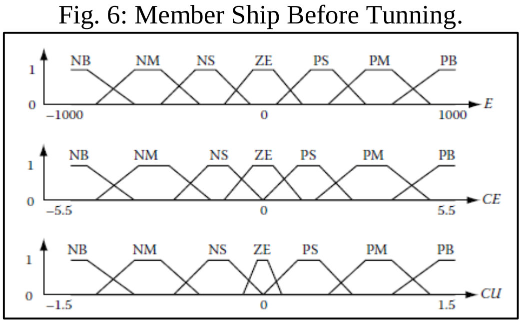

Fig. 7: Member Ship After tunning. [2]

VIII. SIMULATION AND RESULTS

Here we have taken standard second order transfer function

$$y = \frac{1}{(s+1)^2}$$

First we tune this system with PID and later on from the gains of PID we tune fuzzy system

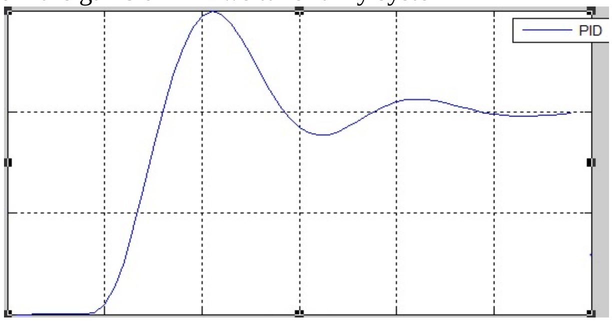

Fig. 7: PID Controller response.

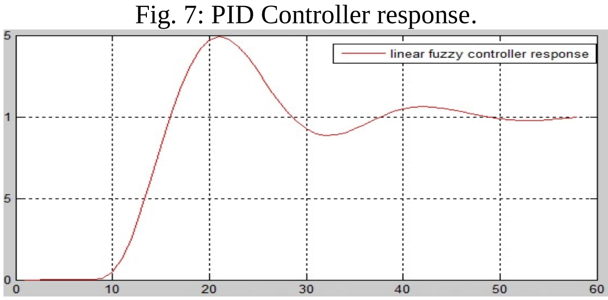

Fig. 8 :-Linear fuzzy Controller response .

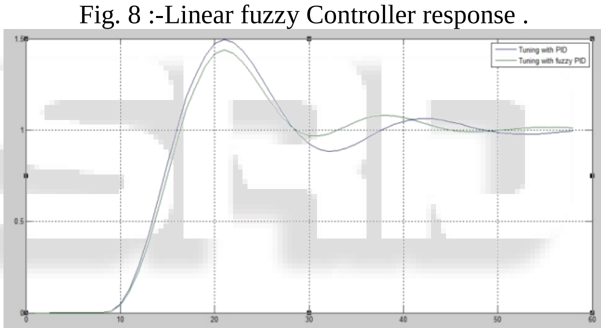

Fig. 9 : Comparision of Fuzzy vs PID response .

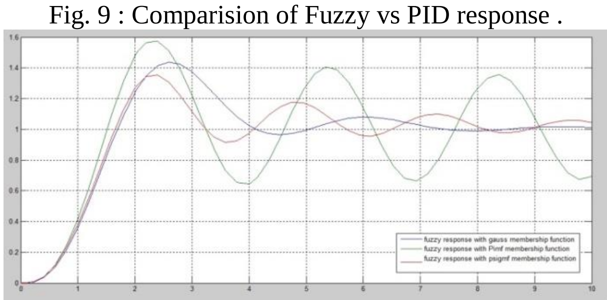

Fig. 10 : Comparision of various membership function

IX. CONCLUSION

In this paper we have successfully simulated fuzzy PID. The processes we used is first we tune our transfer system with PID, and we calculated Kp, Ki, Kd. and from that we have simulated fuzzy PID. Fuzzy PID is successfully simulated in MATLAB. Fuzzy PID gives better response in comparison with crisp PID. We can increase the response time by fine tuning the by given above proposed methods.

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