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Implementation of Pre Compensation Fuzzy For a Cascade PID Controller Using Matlab Simulink

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Abstract:

Fuzzy logic control technology has been widely and successfully utilized in numerous industrial applications. Since fuzzy logic with humanlike but systematic properties can convert linguistic control rule based on expert knowledge into automatic control strategies, it can be well applied to control the process with un modeled and nonlinear dynamics. In this paper a fuzzy logic based pre compensation scheme for PID controller is proposed. Fuzzy methods can be used effectively to implement conventional control methods for performance improvement. The scheme is based on graphically studying the source of steady state errors arising from applying PID type schemes of systems with dead zones. This work is based on trying to compensate for overshoot and undershoot by the transient response. This is easy to implement in practice since an existing PID controller can be used in conjunction with the fuzzy pre compensator without modification

Keywords: Fuzzy controller, PID Controller ,Fuzzification, Defuzzification.

1. Introduction

PID controllers are widely used in process industries to control various processes.PID controller applicability is for linear process. PID controller produces a poor response for large load disturbances. Therefore proper tuning is necessary to the controller to give a satisfactory response. To overcome these disadvantages we propose a scheme called fuzzy pre compensator for a PID controller.

1.1 Advantages of fuzzy pre compensator

No need for precise tuning.

It reduces 90% of overshoot which occur in the PID controller.

It acts as an adaptive controller.

It has faster settling time.

1.2. Disadvantage of fuzzy pre compensator

The complexity involved in forming the fuzzy membership function is to be considered.

2. Fuzzy Precompensated PID Controller

2.1 Control structure

Figure.1 illustrates the basic control structure. The scheme consists of a conventional PID control structure together with the proposed fuzzy pre compensator.

The pre compensator uses the command input ym and the plant output yp to generate a pre compensated command output y1 m described by the following equations

$$\Delta e(k) = e(k) - e(k-1) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

$$\gamma(k) = F[e(k), \Delta e(k)] \ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

$$y1m(k) = ym(k) + \gamma(k). \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

In the above, e(k) is the tracking error between the command input ym(k) and the plant output yp(k), and e(k) is the change in the tracking error. The term F[e(k),e(k)] is a nonlinear mapping of e(k) and Δ e(k)based on fuzzy logic described below. The term $\gamma(k) = F[e(k), \Delta e(k)]$ represents pre compensation or correction term so that the compensated command signaly1m(k) is simply the sum of the external command signal ym (k) and $\gamma(k)$. The correction term is based on the error e(k) and Δ e(k). The compensated command signal y1m(k) is applied to a conventional PID controller as shown in figure 1.a The equations determining the PI controller are as follows.

$$e1(k) = y1m(k) - y(k) \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

$$\Delta e1(k) = e1(k) - e1(k-1) \ldots\ldots\ldots\ldots\ldots (6)$$

$$u(k) = u(k-1) + Kp\,\Delta e1(k) + K1\,e1(k) .. (7)$$

The quantity e1(k) is the pre compensated tracking error of the pre compensated command input y1 m (k) and the plant output yp(k), and Δ e1(k) is the change in the pre compensated tracking error. The control u (k) is applied to the input of the plant.

The purpose of the fuzzy pre compensator is to modify the command signal to compensate for overshoots and undershoots present in the output response when the plant has unknown nonlinearities. Such nonlinearities can result in significant overshoots and undershoots if a conventional PID control scheme is used. The pre compensator uses fuzzy logic rules that are based on the above motivation.

3.Fuzzy precompensater

The implementation of the fuzzy logic based term is $\gamma(k) = F[e(k), \Delta e(k)]$. .In the description standard terminology is used to form fuzzy set theory, for a treatment of fuzzy sets, e(k), and Δ e(k) as inputs to the map F, and $\gamma(k)$ as the output. Associated with the map F is a collection of linguistic values,

$$L = \{NB, NM, NS, ZO, PS, PM, PB\}$$

these values represent the term set for the input and output variables of F. In this case seven linguistic values are used. The meaning of each linguistic value in the term set L should be clear from its mnemonic; for example, NB stands for negative big, NM for negative medium, NS for negative small, ZO for zero and likewise for the positive (p) linguistic value. Associated with the term set L is a collection of membership functions.

$$\mu = \{ \mu NB, \mu NM, \mu NS, \mu ZO, \mu PS, \mu PM, \mu PB \}$$

Each membership function is a map from the real line to the interval [-1 +1]. Figure .2a shows a plot of the membership functions. In this application the MF used is the triangular type. The height of the MF in this case is one, which occurs at the points –1, -0.4,-0.25,0 0.25,0.4,1 respectively.

The realization of the function F [e (k), Δ e (k)] deals into the setting of linguistic values. This consists of scaling the inputs e (k) and Δ e(k) appropriately and then converting them into fuzzy sets. The symbol Ce for the scaling constant for the input e (k) and the symbol CΔe for the scaling constant for the input Δ e (k). For each linguistic value $l \in L$, assign a pair of numbers ne(l) and nΔe(l) to the inputs e(k) and Δ e(k) via the associated membership function

$$ne(l) = \mu l\,(Ce\, e(k)) \ldots\ldots\ldots\ldots\ldots (8)$$

$$n\Delta e(l) = \mu l\,(C\Delta e\, \Delta e(k)) \ldots\ldots\ldots\ldots (9)$$

The numbers ne(l) and nΔe(l), l L are used in the computation of F[e(k), Δ e(k)].

4. Decision making process

Associated with the decision making process is a set of fuzzy rules R = {R1, R2…Rr}, where r is the total number of rules. Each RI, I = 1,2,3,...r, is represented by a triplet (li Δ, li Δc, li γ), where li Δ, li Δc, li γ L.

The first two linguistic values are associated with the input variables e(k), and Δ e(k) while the third linguistic value is associated with the output. An example of a rule is the triplet (NS,PS,ZO).Rules are often written in the form: "if e(k) is le and Δe(k) is l Δe then γ is lγ ".For example, in the rule represented by the triplet (ZO,NS,NM), the idea of the rule is that if e(k) is zero and Δe(k) is negative small, then output is negative medium. The set of rules used in this fuzzy pre compensator is given in table 1. There are 47 rules.

These rules are derived by using a combination of experience, trial and error and the knowledge of the response of the system. These are common approaches to the design of fuzzy logic rules as.

To explain how these rules were obtained, consider for example the rule (ZO,NM,NM) in table1. Suppose the command signal is a constant ym, the error e(k) is zero and the change of error Δe(k) is negative number. This means that the output yp (k) is increasing, i.e, heading in the direction of an overshoot.

To compensate for this, the command signal is to be decrease. This corresponds to applying a correction term γ(k) as negative. Hence rule "if error is zero and change of error is negative medium, then output is negative medium, correction term". Similarly all rules are made.

5. Defuzzification stage

Defuzzification strategy is a mapping from a space of fuzzy control actions defined over an output universe of discourse into a space of no fuzzy control actions. It is employed because in practical applications a crisp action is required. It is aimed at producing a non-fuzzy control action. However, in this part center of area defuzzification is applied.

$$\gamma(K) = \int \mu \leq (\gamma)\gamma d\gamma \text{ x } C\gamma \text{ .... } (10)$$

$$\mu \leq (\gamma)d\gamma$$

Where ∫ denotes algebraic integration

Function of γ is also selected as triangular shape function as shown in the figure 2.c since the output signal is normalized to the range from –1 to +1 the output command will exit and absolute value.

6. Conclusion

The design methodology of fuzzy pre compensator and fuzzy rules for cascade PID controller were discussed, also the performance of the fuzzy pre compensator for a cascade PID control is tested by using matlab simulink as shown in figure 1.b.

7. Results and discussion

The Performance of PID Controller and FPC Controller (Simulation)

By comparing the results from figure3 we can conclude that the response obtained using FPC (Fuzzy Pre Compensator) controller is better than the conventional PID controller. Even if the process parameter changes the FPC controller adapts itself and produces good response. Hence it acts as an adaptive controller.

We observed that conventional PID controller is not able to follow the set point but FPC controller follows the set point. The conventional PID controller gives a damped oscillation but FPC controller produces good response. Hence FPC controller does not require precise tuning.

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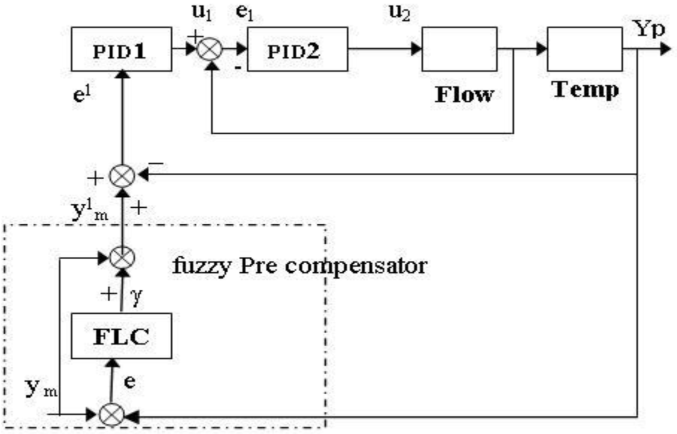

Figure 1.a: Basic Control Structure of Fuzzy Pre-compensator Cascade Control

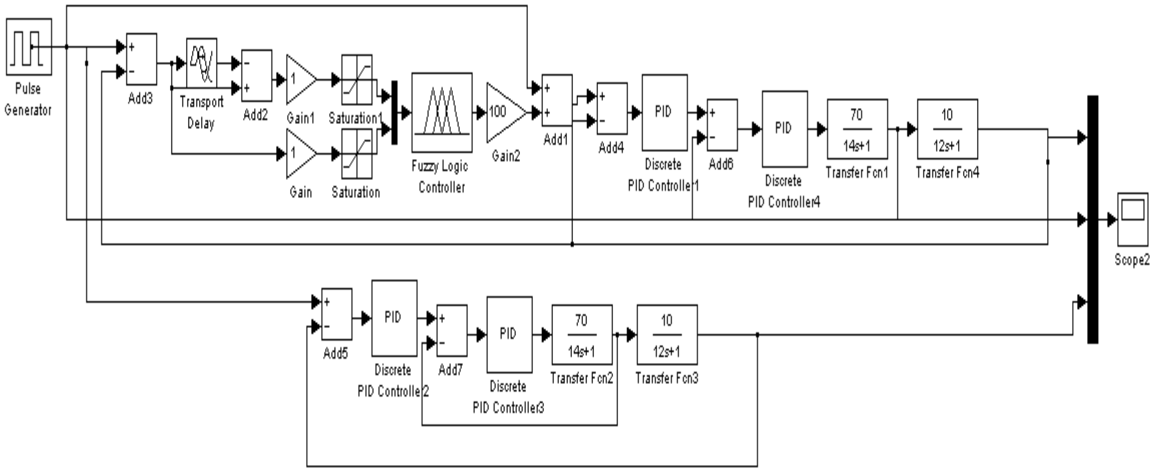

Figure 1.b : System implemented in Matlab Simulink

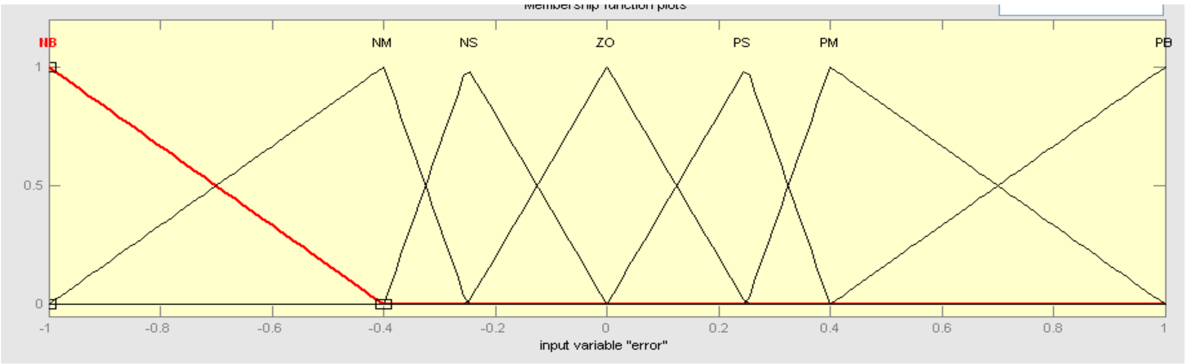

Figure 2.a: Membership function of error (e)

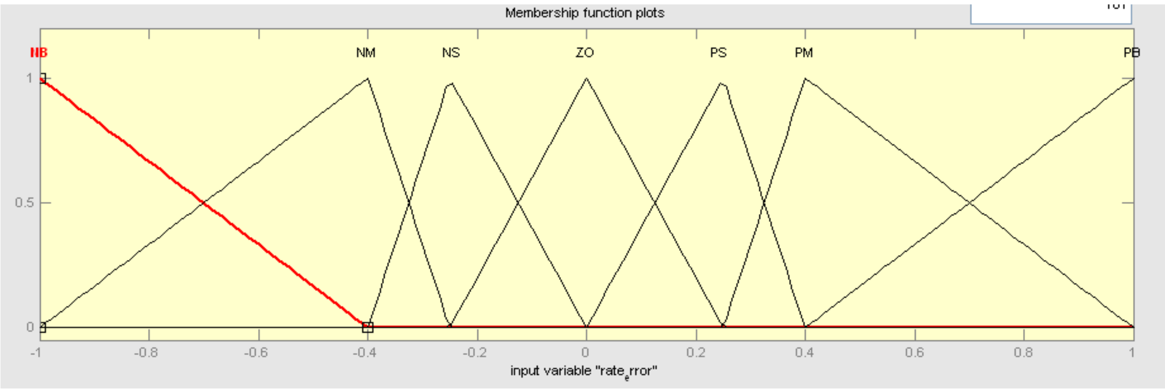

Figure 2b: Membership function of change in error (Δ **e**)

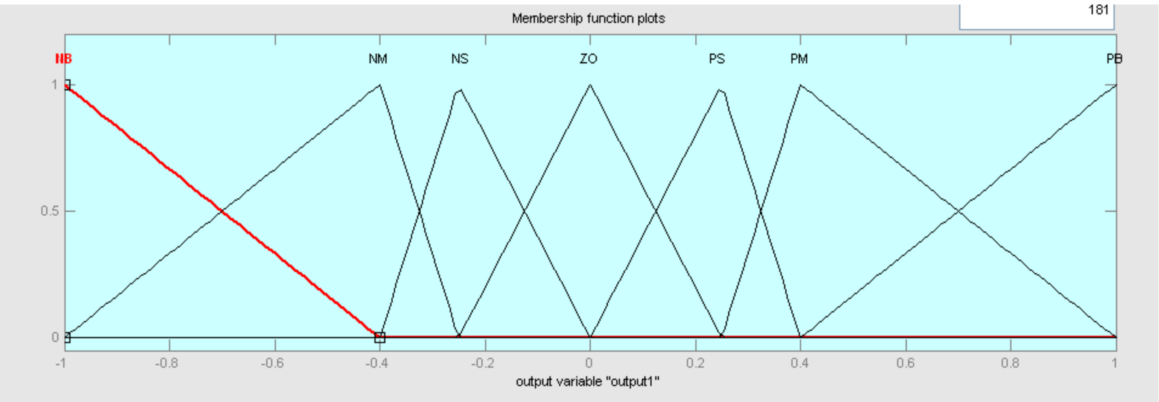

Figure 2.c: Membership function of Controller output (γ)

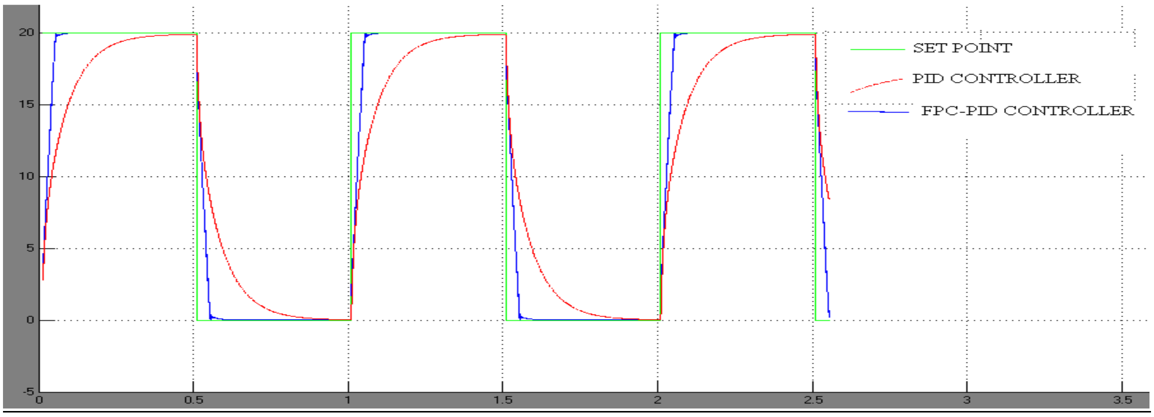

Figure 3: Response of FPC and PID controller for varying Set point with continuous load disturbance

Table 1.: DML rule table of the FLC

Δe **e**	NB	NM	NS	ZO	PS	PM	PB
NB	NB	NB	NB	NM	NS	NS	ZO
NM	NB	NB	NM	NS	NS	ZO	PS
NS	NB	NM	NS	NS	ZO	PS	PM
ZO	NM	NM	NS	ZO	PS	PM	PM
PS	NM	NS	ZO	PS	PS	PM	PB
PM	NS	ZO	PS	PS	PM	PB	PB
PB	ZO	PS	PS	PM	PB	PB	PB

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