Comparative Study of Fuzzy PD Controller and Conventional Controllers

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***Abstract*—In this articale we present a PD-type fuzzy controller. The performance of PD-type fuzzy controller is compared with that of conventional controllers like PD, PI and PID controllers. the effectiveness of the scheme is established through simulation experiments on various types of second order processes such as i) Marginally stable ii) Stable and linear and iii)unstable system. The performance of PD-type fuzzy controller is compared with that of conventional controller for each process. For a clear comparison between the conventional and FLC's several performance measures such as, peak overshoot (%OS), setting time (t_s), rise time(t_t), integral absolute error (IAE) are used. each process is tested with set-point change. The results for various types of process reveals the conventional controllers are not suitable for higher order and non-linear process especially for unstable process**

Keywords—PD-Type Fuzzy Controller, Membership Functions.

I. INTRODUCTION

In this article we present PD-type Fuzzy Logic Controller (FLC). The proposed Fuzzy PD-Controller is designed using a very simple Control rule base and most natural and unbiased membership functions (MFs). The effectiveness of the scheme is established through simulation experiments on various types of second order processes such as a) Marginally Stable b) Linear and c) Non-minimum phase-pole (unstable) systems. Performance of the proposed Fuzzy PD-controller is compared with that of its conventional counterpart with respect to set-point change using several performance indices. Like conventional non-fuzzy controllers, mainly three types of FLC's i.e. PI, PD, PID are considered for process control applications. Among them PID-Type FLC's are rarely used due to the difficulties associated with the formulation of an efficient rule-base and findings of its large number of parameters. PI-Type FLC's are most common and practical[4].

II. DESIGN OF THE PROPOSED CONTROLLER

A. *Membership Functions*

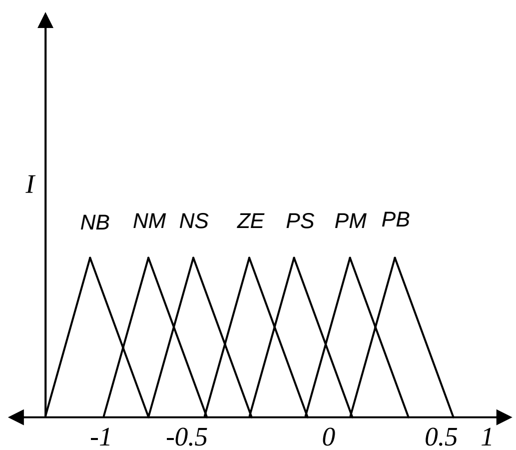
The MF's for control inputs i.e. 'e' and 'Δe' and control output i.e., 'u' are defined on the common normalized domain [-1, 1], we use symmetric triangles with equal base and 50% overlap with neighboring MF's as shown in Fig.2.1

B. *TheRule - Base*

The controller output (u) is determined by rules of the form

R_{PD}: If 'e' is E and 'Δe' is ΔE. Then 'u' is U.

The rule base for computing 'u' is shown is Table-I. This is very often used rule-base designed with a two dimensional phase plane where the FLC drives the system into the so called sliding Mode.



NB: Negative Big
NM: Negative Medium
NS: Negative Small
ZE: Zero
PS: Positive Small
PM: Positive Medium
PB: Positive Big

Fig.1 Triangular membership function

III. RESULTS

We now show the simulation analysis for some typical 2nd order system. The comparative performance of the two controllers are tabulated for each process. For an easy performance comparison, rise time for both FPDC and conventional controllers are maintained almost at the same value. IAE reflect transient behavior of a controller. In all cases mamdani type interfacing[3] and height method[2] of defuzzification are used. Now we present the performance analysis of the proposed controller for different processes.

C. *Zero-Load Processes*

Linear second-order process (marginally stable) consider the process described by $Y(s) = 1/5s^2 + s$ ………….. (1).

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Table. I. Rule Base

Δe/e	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NM	NS	NS	ZE
NM	NB	NM	NM	NM	NS	ZE	PB
NS	NB	NM	NS	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PS	PM	PB
PM	NS	ZE	PS	PM	PM	PM	PB
PB	ZE	PS	PS	PM	PB	PB	PB

Ziegler-Nichols tuning formulae is widely known as a fairly accurate heuristic method for determining good settings of PI and PID controllers for a wide range of common industrial process Fig. 2, table II shows the comparative performance of Ziegler-Nichols tuned PID controller and FPDC for the process. Fig2, table-II reveals the excellent performance of FPDC over conventional PID controller.

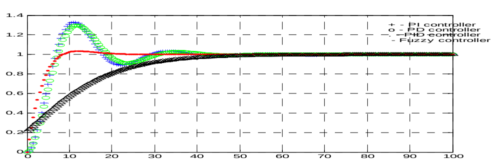

Fig.2 Transient behaviour of Zero Load Process

D. *Non-Zero-Load Process*

Though PD controllers are not usually recommended for non-zero-load processes due to the presence of large steady state errors, here, for completeness and to have a sense of how well the proposed scheme performs, we present some results for such systems[1].

$H(s) = 2.5/S^2 + S + 0.2$…………(2)

Here proposed controller shows the much better performance than the conventional controllers.

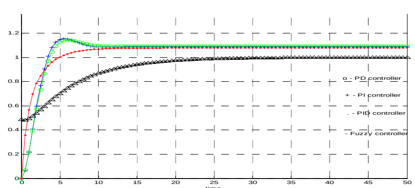

Fig.3 Transient behaviour of Non-Zero Load Process

E. *Non-Minimum Phase System (Unstable System)*

$H(s) = 1/(1-S^2)$ …………(3)

This is unstable due to the presence of pole in the R.H.S of s-plane at S = +1. So PI controller is not applicable for this system, it introduces extra pole at the origin (s=0). On the other hand PD controller introduces zero in the LHS of s-plane. Therefore by pole-zero cancellation the system may be stable under a PD controller[5]. The performance of this process is shown in fig no.4 and in table no.II.

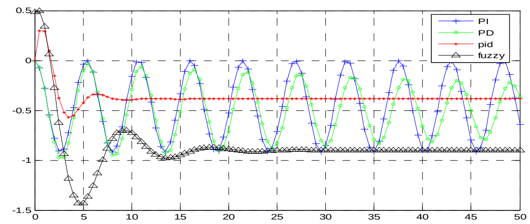

Fig.4 Transient behaviour of Non-Minimum phase System

IV. CONCLUSIONS

We proposed PD-type fuzzy logic controller. The most important features of the proposed scheme is that it gives better response than any other conventional controllers. though the proposed controller is mainly developed for single input and single output (SISO) system. It may be used for non-interacting (uncoupled) multi input and multi output (MIMO) systems using one such controller for each controlled variable. Conventional controllers cannot give good results for process with the integration (Zero load process), even Ziegler – Nichols tuned PID controller fail to provide a satisfactory performance for such time In such a situation fuzzy controller may exhibit very good performance.

Table. II. Performance Indices of the Proposed System

Controller		*Performance indices*			
		%OS	t_s	t_r	*IAE*
Zero Load Process	PID	76.11	32.1	33.3	5.341
	FPDC	39.58	6.96	7.0	5.294
Non-Zero Load Process	PID	40.11	34.1	4.2	7.413
	FPDC	20.11	6.9	2.1	4.59
Non-minimum Phase	PID	89.1	34.5	3.8	9.132
	FPDC	39.19	3.0	0.8	1.15

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