DESIGN OF TUNING METHODS OF PID CONTROLLER USING FUZZY LOGIC

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ABSTRACT

The purpose of this project tries to explore the potential of using soft computing methodology in controllers and their advantages over conventional methods. PID controller is mostly used for industrial applications. There are various systems for the designing of PID controller and it is used to control the different parameters like settling time, rise time, overshoot, peak gain and phase margin, stability etc of the plant. The conventional PID controller is not very efficient due to the presence of non linearity in the system of the plant and also it has a quite high overshoot and settling time.

The main focus of this project is to apply soft computing technique that is fuzzy logic to design and tuning of PID controller to get better dynamic and static performance at the output. This project also discusses the benefits the soft computing methods.

Keywords: PID controller, Fuzzy logic.

INTRODUCTION

Conventional PID controller:

Proportional- integral- derivative (PID) controllers have been used for industrial purpose due to their simplicity, easy designing method, low cost and effectiveness. Due to presence of non linearity in the system, conventional PID controller is not very efficient. Proportional (P), integral (I) and derivative (D) are the three main parameters of the PID controller. The values of these three parameters interpreted in terms of time ,where ,’P’ depends on the present error, ’I’ on the accumulation of past errors and ’D’ is a prediction of future errors, based on current rate of change. By tuning the three parameters in the algorithm of PID controller, the controller can provide control action designed for specific process requirements.

The proportional, integral and derivative terms are summed to calculate the output of the PID controller.

The final output defined by u (t) and it given by

$$u(t) = K_p e(t) + K_i \int_0^t e(x).dx + K_d \frac{de(t)}{dt}$$

Where K_P — proportional gain, a tuning parameter

K_i —integral gain, a tuning parameter

K_d — derivative gain, a tuning parameter

e — error present in the controller

t —time or instantaneous time

x—variable of integration, taken from time 0 to present 1

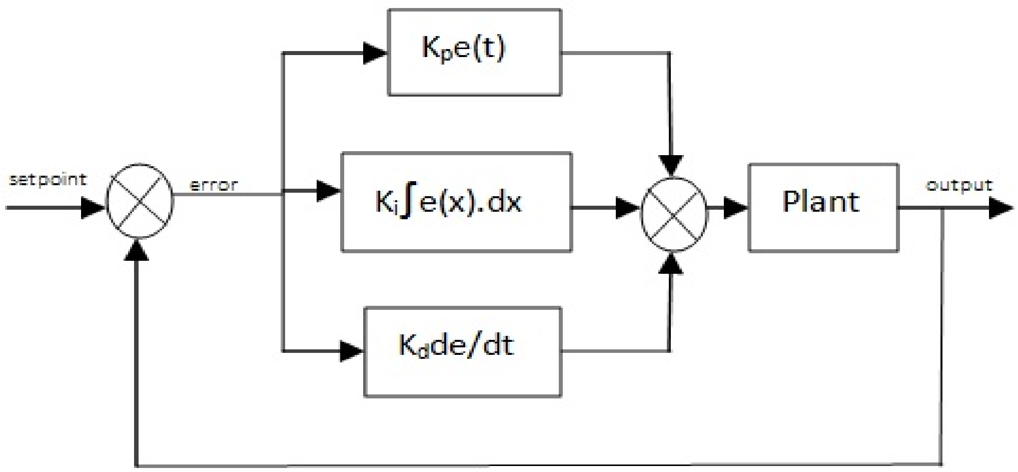

Fig 1:Block diagram of conventional PID controller

TUNING OF PID PARAMETERS

Tuning of a PID controller refers to the tuning of its various parameters (P,I,D) to achieve an optimized value of the desired response .The necessity of tuning of the parameter of PID controller is very important. ZIEGLER-NICHOLS method is one of the mostly used tuning method of PID controller.

Ziegler-Nichols proposed rules for determining the values of the proportional gain K_p, integral time K_i and derivative time K_d based on the transient –response characteristics of a given plant.

In the Ziegler-Nichols method if the plant involves neither integrators nor dominant complex conjugate poles, then such a unit step response curve may look like as S-shaped curve as shown in fig below -

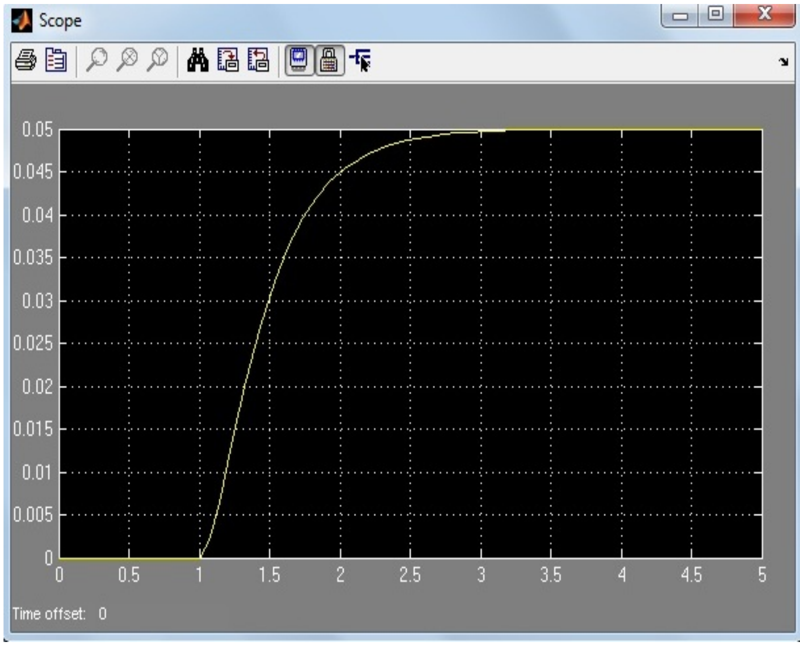

Fig 2: S-Shaped Curve

This S-shaped curve characterized by two constants the delay time 'L' and a time constant T-determined by drawing a line tangent to the S-shaped curve at the inflection point.

The value of Kp, K_i and K_d can be calculated by using the formula that

$$K_p=1.2T/L; \ K_i=2L; \ K_d=0.5L \quad ......(i)$$

From the fig 2 .

Delay time (L) = 0.9sec

Time constant (T) = 0.9sec

Substituting the values of L and T in equation (i) ,

K_p = 1.2; K_i = 1.8; K_d = 0.45

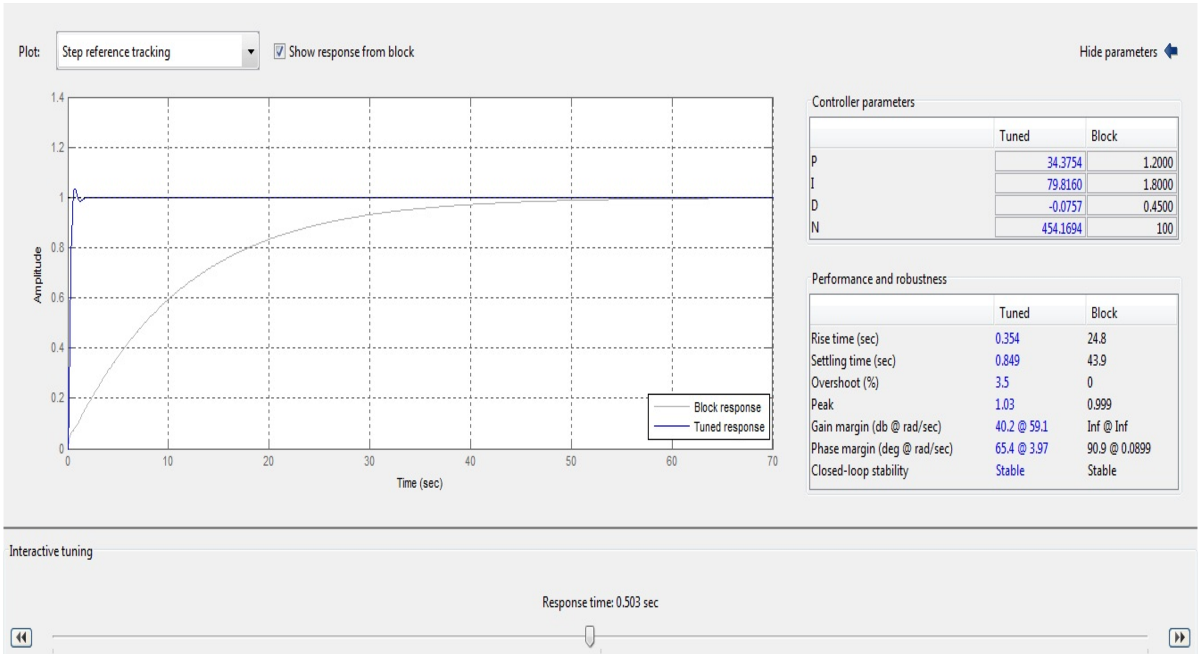

Fig 3: Simulation result of Ziegler-Nichols Method

In conventional PID controller there is some overshoot, large amount of settling time and rise time. But in Ziegler Nichols method the overshoot is completely eliminated but rises time and settling time is greater than the conventional PID. In general, Ziegler Nichols methods has provided starting point of fine tuning so the tuning is necessary to get the appropriate value. After tuning of this PID controller both the rise time and settling time will be reduced by a large amount and there is some overshoot but anyway it is very less compare to conventional PID controller.

FUZZY LOGIC

Fuzzy logic is a superset of conventional logic that has been extended to handle the concepts of ‘completely true’ and ‘completely false’ values. As its name suggests, it is the logic underlying modes of reasoning which are approximate rather than exact. The importance of Fuzzy logic derives from the fact that most modes of human reasoning and especially common sense reasoning are appropriate in nature. Fuzzy logic is having many values. Here these appropriate values are not fixed time traditional binary sets. So, it is having a truth value that ranges in degree between 0 and 1. Therefore this type of logic system is able to address the values of variables those lie between completely truths and completely false. The variables are called the linguistic variables and each linguistic variable is described by a membership function which gives the probable decision making is an important part of the fuzzy logic. The decision making is mainly the combination of concepts of fuzzy set theory, fuzzy IF-THEN rules and fuzzy reasoning. The fuzzy system makes use of if then statements and with the help of connecters (such as AND gate) necessary rules are constructed. The fuzzy logic controller (FLC) has been proposed to get better performance in conventional PID controller and for the purpose of fuzzification and defuzzification the Mamdani fuzzy system and mean of maximum methods are used respectively.

The Fuzzy Logic Controller:

The ideas of fuzzy set and fuzzy control are introduced by Zadeh. Fuzzy logic controllers are applied to many systems with linearity and uncertainty. The structure of fuzzy system can be classified according to the different applications. One of the most popular types is the error feedback fuzzy controller, which is called fuzzy logic controller (FLC). In conventional FLC, there are also PD-type FLC, PI-type FLC and PID-type FLC.

Principle of FLC:

The FLC having the following stages:

1) FUZZYFICATION:

Fuzzyfication implies the process of the transforming the crisp values of inputs of a controller to the fuzzy domain.

2) KNOWLEDGE BASE:

The knowledge base of FLC consists of data base and rule base

i)DATA BASE

It is used to provide necessary information for functioning of fuzzification module, rule base and defuzzification module.

ii) RULEBASE

The function of rule base is to represent in a structured way the control policy.

3) FUZZY INFERENCE SYSTEM:-

Fuzzy inference system has a simple input -output relationship. Input data from the external world is processed by the fuzzy inference system to produce the data the events having place in this process are referred as the basic fuzzy inference algorithm. Mamdani fuzzy is one of the examples of fuzzy inference system.

4) DEFUZZIFICATION:-

It is a process of transforming the fuzzy sets assigned to a control output variable into a crisp value. There are various methods of defuzzification but we used the mean of maximum method (MOM).

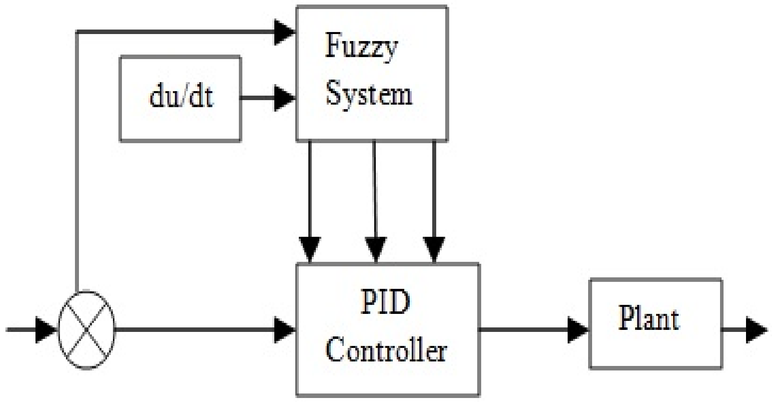

Fig.4 Block diagram of fuzzy PID controller

Table. Basic rules table for mamdani system

u(t)		|e|						
		NB	NM	NS	ZO	PS	PM	PB
|ec|	NB	NB	NB	NB	NB	NS	ZO	ZO
	NM	NB	NB	NM	NM	ZO	ZO	PS
	NS	NB	NM	NM	NS	ZO	PS	PM
	ZO	NB	NM	NS	ZO	PS	PM	PB
	PS	NM	NS	ZO	PS	PM	PM	PB
	PM	NS	ZO	ZO	PM	PM	PB	PB
	PB	ZO	ZO	PS	PB	PB	PB	PB

Here |e| is the error and |ec| is the rate of change of error.

Basic rule for making this table:

a) When |e| is bigger value ,K_p should be bigger ,k_d should be smaller for better tracking performance and the K_i should be set to zero for avoiding integral saturation and heavier overshoot.

(b) When |e| and |ec| are middle value, neither K_p, K_i and K_d is too large for slight overshoot. K_i should be smaller while K_p and K_d should be moderate for rapid response.

(c)When the |e| is smaller value, both K_p and K_i should be increased for better steady performance .K_d should be moderate for avoiding oscillation around the corresponding static value.

Meaning of the linguistic variables in the fuzzy interference system:

NB- Negative Big

NM- Negative Medium

NS- Negative Small

ZO- Zero

PB-Positive Big

PM- Positive Medium

PS- Positive Small

SIMULATION RESULT

We have considered the following second order transfer function

$G(s) = 1/(s^2+10s+20)$

The response of the fuzzy self-tuning PID controller is obtained using MATLAB and simulink.

A two-input and there output fuzzy controller is created and membership functions and the fuzzy rules are determined.

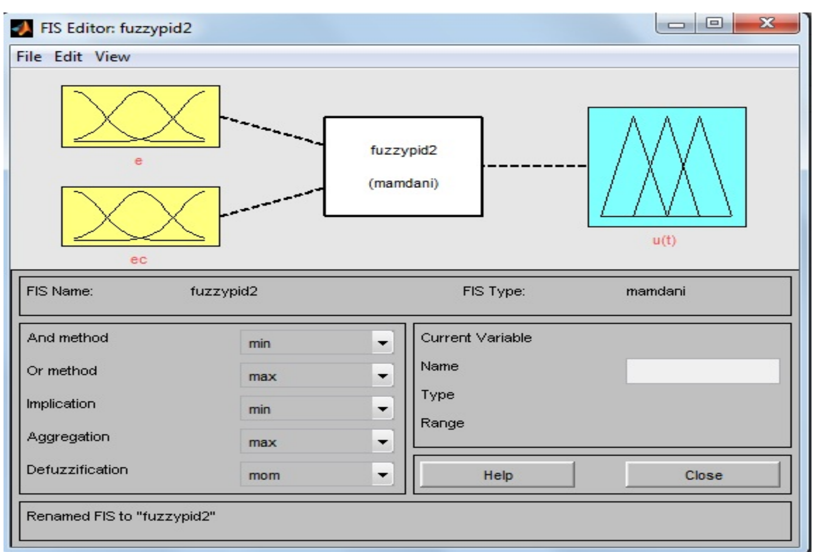

Fig. 5 Mamdani fuzzy system

Consider Kp=1.2, K_i=1.8, K_d=0.45

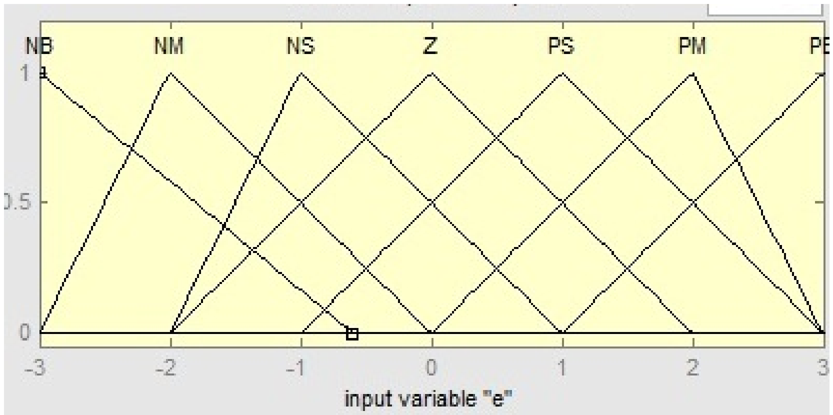

Fig. 6: Membership function for 'e

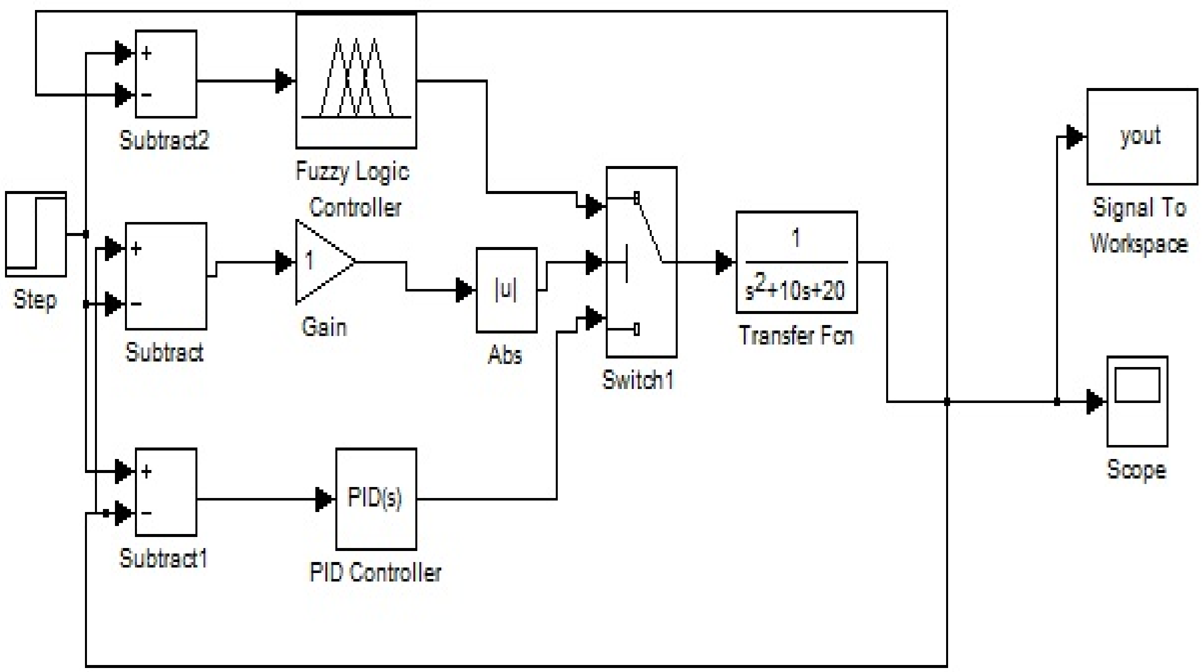

Fig.7:Block diagram of Fuzzy PID controller

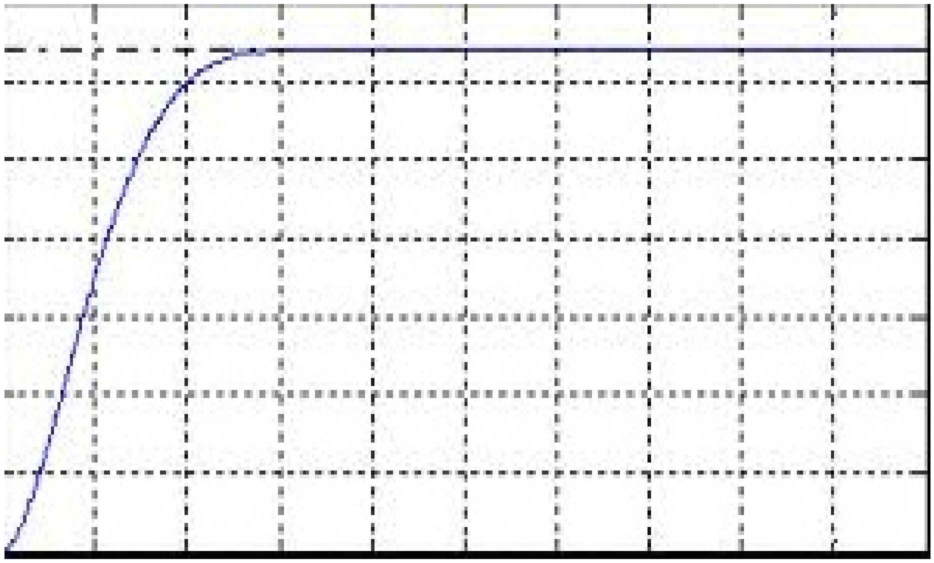

Fig.8 : Output response of Fuzzy PID controller with no overshoot, less settling time and less rise time

Value of percentage of overshoot 0(%) achieved by the examined controllers tuned by Ziegler Nichols method and Fuzzy logic controller.

Ziegler Nichols	0
FLC	0

Value of rise time (t_r) achieved by the examined controllers tuned by Ziegler Nichols method and fuzzy logic controller.

Ziegler Nichols	24.8
FLC	9.8

Value of settling time (t_s) achieved by the examined controllers tuned by Ziegler Nichols method and Fuzzy logic controller.

Ziegler Nichols	43.9
FLC	14.7

CONCLUSION:

In this paper, two different methods regarding the tuning at conventional PID and fuzzy logic controller has been presented. Ziegler Nichols method is used for tuning of conventional PID controller. But this method is not satisfactory for many systems. This method gives the approximate value of any response not the appropriate or exact value and it is having one more disadvantage that the rise time and settling time will be more .For better performance to reduce the settling and rise time for getting better response. To get the better performance it is necessary to reduce both the rise time and settling time simultaneously and for this purpose Fuzzy logic technique can be used because it is a type of logic controller (FLC), which will successfully eliminate the whole overshoot from the output response. On the other hand settling time and rise time will be also reduced. The simulation results shows that compared to the traditional PID controller, fuzzy self-tuning PID controller has a better dynamic response curve, shorter response time, small overshoot, high steady precision, good static and dynamic performance.

To get the better performance in PID controllers genetic algorithm can be used for further future development. In which the principles of evolution, natural selection and genetics from natural biological system in a computer algorithm to simulate evolution can be used.

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