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Fuzzy Logic based Position Control System for Tracking Application

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ABSTRACT

This paper describes the efficient simulation model for fuzzy logic control of DC motor drives using Matlab/Simulink. Two types of controller that is PID and fuzzy logic controller will be used to control the output response. The scope of this project is to apply the fuzzy logic controller for position control of DC motor. The performance of the designed fuzzy and conventional PID position controllers for DC motor is compared and investigated. Finally, the end result shows that the fuzzy logic approach has minimum overshoot, which shows the more effectiveness and efficiency when compared with Conventional PID model. The PID controllers not have a good performance because of the non-linear features of DC motors like saturation and friction.

Keyword: Fuzzy logic controller, PID controller, DC motor, Position control.

1. INTRODUCTION

All control systems undergo from problems related to unwanted overshoot, longer settling times and vibrations and stability while going away from one state to another state. Real world systems are nonlinear, accurate modeling is difficult, costly and even not possible in most cases. The conventional digital control systems like classic PID solve the on top of problems just about but we need to quick and exact control systems to acquiring desired response. It is necessary to know system's mathematical model or to make some experiments for tuning PID parameters. However, it has been known that conventional PID controllers generally do not work well for non-linear systems, and Particularly complex and unclear systems that have no precise mathematical models. To overcome these difficulties, various types of modified conventional PID controllers such as auto-tuning and adaptive PID Controllers were developed lately. There are three basic approaches to intelligent control: knowledge based expert systems, fuzzy logic, and neural networks. All three approaches are interesting and very promising areas of research and development. At present, fuzzy control application face a multiplicity of practical systems, for example the train operation, parking control of a car, heat exchanger, robots, and are in many other systems, such as home appliances, video cameras, elevators, aerospace, etc. In this paper, fuzzy logic method has been developed.

Two types of direct current (DC) motors are studied to examine the performance correspond to various design methods to design PID-like FLC. DC motors are classified into several broad categories. The DC motors have separately excited-field, in which the field winding is separate from the armature. They are either armature controlled with fixed field or field-controlled with fixed armature current[3] , as shown in Figure 1.

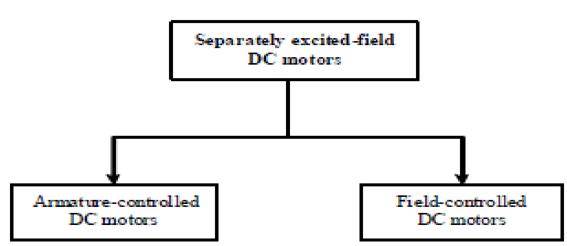

Fig.1:Separatly excited-field DC motor

The control objective for both types of DC motors is to reach a specified motor position using an appropriate input drive voltage.

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2. MOTOR MODELING

The figure 2 shows the equivalent model of DC motor.

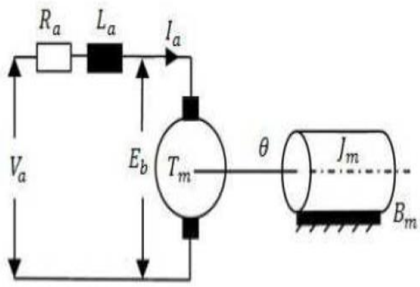


Fig 2: DC Motor Model

$V_a(t)=R_a.i_a(t)+L_a.\frac{dia(t)}{dt}+e_b(t)$ …….(1)

$E_b(t)=K_b.w(t)$ ……….(2)

$T_m(t)=K_T.ia(t)$ ……….(3)

Where,

v**a**= armature voltage (v)
R**a**= armature resistance (Ω)
L**a**= armature inductance (H)
ia= armature current (A)
E**b**= back emf (V)
Ө(t)= angular speed (rad/s)
Tm= motor torque (Nm)
Ө = angular position of rotor shaft (rad)
Jm = rotor inertia (kgm2)
B**m**= viscous friction coefficient (Nms/rad)
KT = torque constant (Nm/A) and
K**b** = back emf constant (Vs/rad).

Figure 3 shows the model of DC motor which is built by using Simulink. Motor model was converted to a 2-in 1-out subsystem. Inputs are armature voltage (***Va***) and load torque (*T*load) and the output obtained as position (teta).

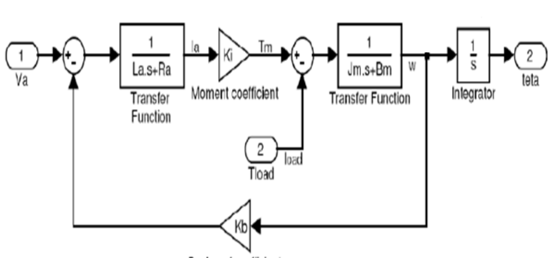


Fig 3: Simulink Model of DC Motor

DC motor plays an important function for fast acceleration and de-acceleration. The mechanical time constants in these motors are bargain by reducing the rotor inertia. Table1 shows the DC motor specifications.

Table I: DC Motor Specifications

Constants	values
Moment of inertia of the rotor	1e-1
Rated motor voltage	6V
Armature inductance	0.1(H)
Armature resistance	0.05(Ω)
Electromotive force constant	0.22
Back E.M.F. Constant	1.5
Damping ratio	10.91

3. DESIGN OF PID CONTROLLER

PID controller is a device which produce an output signal u(t), consisting of three terms, One proportional to input signal e(t), another one proportional to integral of input signal e(t) and the third one proportional to derivative of input signal e(t). So it is called three action controllers. Here the proportional part of the control action repeats the change of error and derivate part of the control action adds an increment of inputs. So that proportional plus derivative action is shifted ahead in time. The integral parts add a further increment of output proportional to the area under the deviation line.

The general equation of PID controller is given below:

$$U(t)=k_p\, e(t)+k_i\int e(t)dt+k_d\frac{d}{dt}e(t) \quad \text{………(4)}$$

where

Kp= proportional gain

Kd= derivative constant or gain
Ki= integrate constant or gain

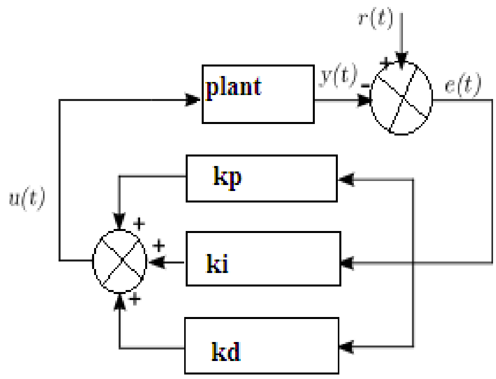


Fig 4: PID Controller Design

In PID controller, two types of tuning method are used to tuning the PID controller. They are :i)Hand tuning method, ii)Ziegler-Nichols method. The hand tuning method is always not used frequently. Hand tuning method is shown in table 2.

Table 2: Hand Tuning Rule

Operations	Rise time	overshoot	Stability
k_p	Faster	Increased	Decreased
k_d	Slower	Decreased	Increased
$1/T_i$	Faster	Increased	Decreased

But this method takes a long time to find the optimal value. The next method as, Z-N method. It is most widely used, because it takes a short time to find the optimal value. The rule of Z-N, tuning is shown in table 3. In this paper, Z-N method is used to find the controller parameter or co-efficient of PID controller.

Table 3: Ziegler-Nichols rules

Controller	k_p	T_i	T_d
P	0.5K	-	-
PI	$0.45K_U$	$T_U/1.2$	-
PID	$0.6K_U$	$T_U/2$	$T_U/8$

The given figure 5 shows simulation diagram of PID controller.

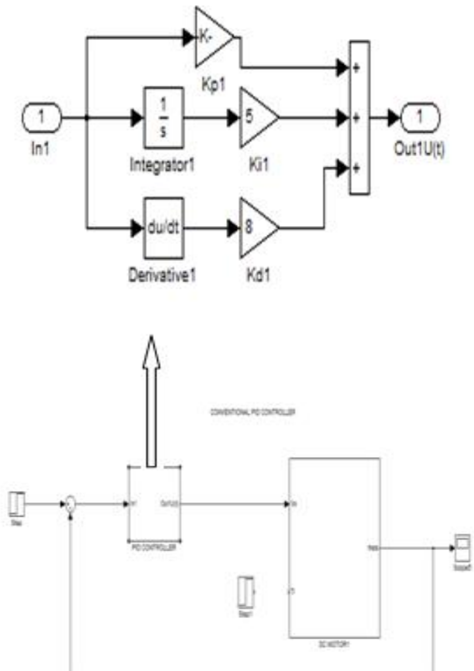


Fig 5: Simulation Diagram for PID Controller

4. DESIGN OF FUZZY LOGIC CONTROLLER

Fuzzy control is a control method based on a fuzzy logic. Just as fuzzy logic can be described simply as "computing with Words rather than Numbers"; fuzzy control can be described as "control with sentences rather than equations". A fuzzy controller can include some experimental rules that are given below:

- *Fuzzification*: convert crisp input into fuzzy sets described by different expressions. Membership functions can be flat on the top, piece-wise linear and triangle shaped, rectangular, or ramps with horizontal shoulders.
- *Inference*: The fuzzy IF-THEN rule expresses a fuzzy implication relation between the fuzzy sets of the premise and the fuzzy sets of the

conclusion. The following steps describe this process:

1. Matching of the facts with the rule premises (determination of the degree of firing *DOF* of the facts to the rule premises).

2. If the rule contains logic connections between several premises by fuzzy AND or fuzzy OR the evaluation is performed by t-norms or t-conorms.

3. Implication: The next step is the determination of the individual rule output. The *DOF* of a rule interacts with its consequent to provide the output of the rule. It will be a fuzzy subset over the output universe.

- *Aggregation*: This process aggregates the individual rule outputs to obtain the overall system output. It will be also a fuzzy subset over the output universe (a union operation yields a global fuzzy set of the output).

- *Defuzzification* to obtain crisp output (various defuzzification methods can be used, as, e.g., center of magnitude, bisector of area, and mean of maximum, to obtain a crisp numerical output value)[3]. The figure 6 shows the general structure of the fuzzy controller.

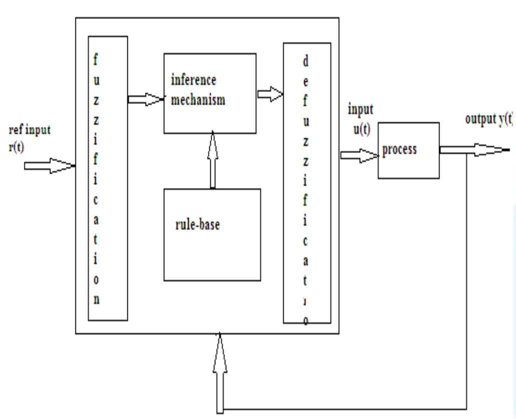
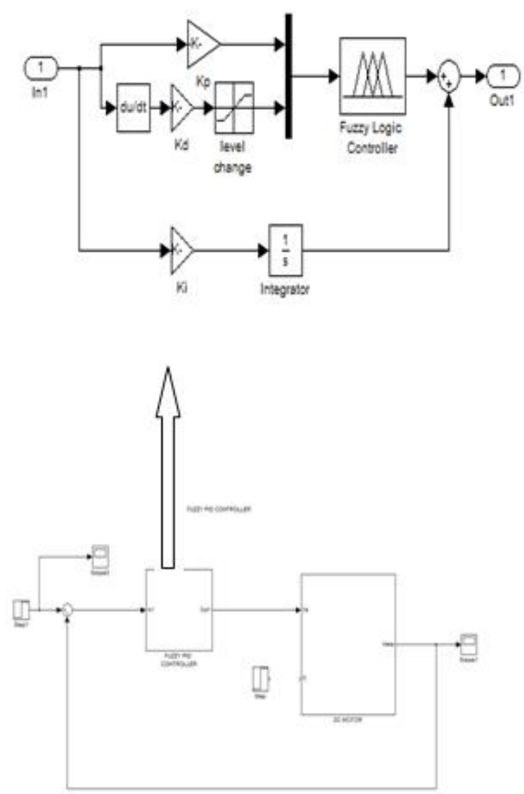
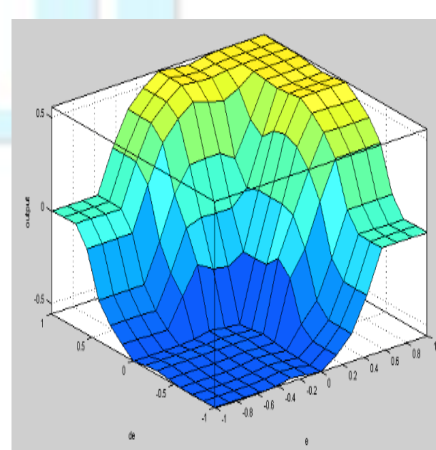


Fig 6: General structure of the Fuzzy Controller

For simulating the design of FLC, we code fuzzy interface system using 'C' language. In the implementation MIN operator is chosen as AND connected between the preceding of the rules of the FLC and as the fuzzy implication operation while MAX is chosen as OR connected between the individual rules. The Center of Area (COA) is chosen as defuzzification. MATLAB/fuzzy logic toolbox is used to simulate FLC which can integrated into simulation with simulink. The FLC designed through the FIS editor. First import the rules from the comment "from file" and then transferred to matlab workspace by the commend "export to workspace". Then the simulink environment provides a direct result of FLC through the matlab work space. The figure 7 shows the Fuzzy controller design.



(a)



(b)

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Fig 7: simulation diagram for fuzzy logic controller: a) simulation diagram b) surface view

In this paper will make do with two dimensional plots. The functions are "error" and "change of error". The input and output variable of FLC consist of three fuzzy sets namely N(negative), Z(zero), P(positive). The function table 4 is given below:

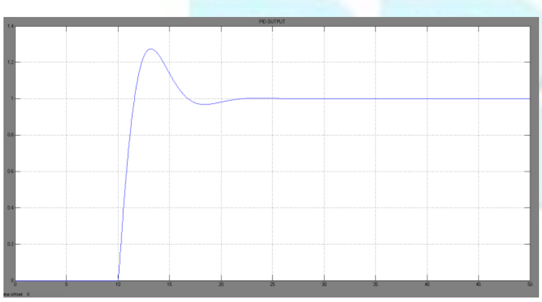
Table 4: Fuzzy Rules

E / De	N	Z	P
N	**N**	**N**	**Z**
Z	**N**	**N**	**P**
P	**Z**	**P**	**P**

5. SIMULATION RESULTS

The output response of both PID and Fuzzy logic controller is shown in figure (8&9). From the simulation results Fuzzy logic controller perform well than the PID controller. Therefore, the proposed control method provides a tool for making use of the fuzzy information in a systematic and efficient manner.

Case i: without step change



Case ii: with step change

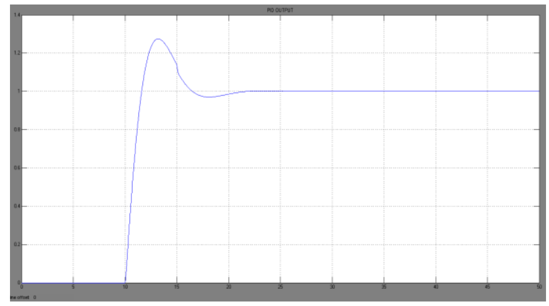
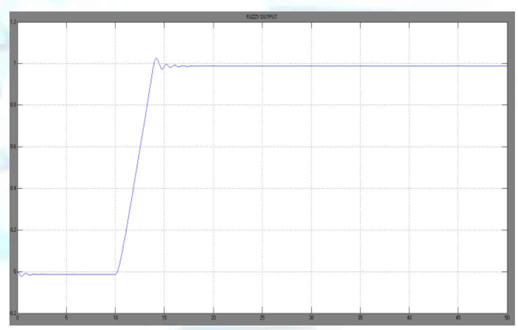


Fig 8: Output Response of PID Controller

The output wave of PID controller is shown in above figure 8, by comparing these two wave forms during without step change the settling time and overshoot is less than when apply the step change.

Case i: without step change



Case ii: with step change

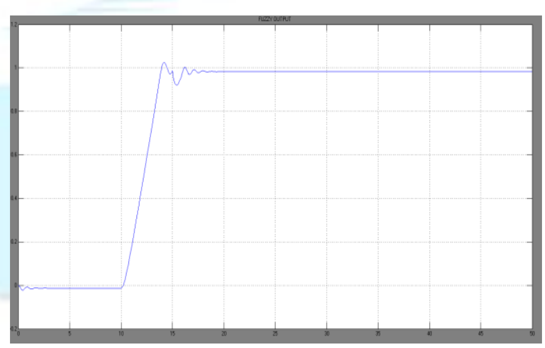


Fig 9: Output Response of Fuzzy Control

The output wave of Fuzzy logic controller is shown in above figure 9, by comparing these two wave forms during without step change the settling time and overshoot is less than the with step change. When it will compare with PID controller, the Fuzzy controller gives the better output response.

6. CONCLUSION

The design of position controlled dc motor system using both conventional PID and FLC has been presented. The PID controller is based on a mathematical model. But the fuzzy controllers are relatively new and use completely different approach then traditional controllers. The fuzzy controllers have the advantages that can deal with nonlinear system and use the human operator knowledge. The fuzzy logic controller is not based on a mathematical model. Comparison results of the conventional PID controller and FLC has been obtained. Finally the FLC gives better response than the conventional PID.

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