Speed Control of DC Motor Using Fuzzy Logic Control and Simulink

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Abstract: Speed control of DC motor plays a vital role for many industrialapplications. The most commonly used controller in the industrial field is the proportional integral derivative controller (PID).PID controller uses mathematical model of the system due to which the output experience percentage overshoot which is not viable for the motor operation. So , in order to overcome this problem we use fuzzy logic controller .In this paper, the role of FLC to control the speed of DC motor is carried out which gives more stable output as compared to PID controller. FLC provides an alternative to PID controller, even when the data is not available for the system. The experiment data is used in FLC which is then applied to the matlab motor model and the output result of the model is observed.

Keywords: DC motor, FLC, PID, Speedcontrol.

I. INTRODUCTION

Industrial as well as other purpose applications such as steel rolling mills, electric trains and robotics the motor drives are very important[2].Because of their simplicity, ease of application, high reliabilities, flexibilities and favorable cost the DC drives has been a longtime backbone of industrial applications like robot manipulators and home appliances where speed and position control of motor are required.

A DC motors gives excellent control of speed for acceleration and deceleration.DC motors have a long tradition of use as adjustable speed machines and a wide range of options have evolved for this purpose. In these applications, motor should be precisely controlled to give the desired performance. The controllers used to control the speed of DC motor to execute one variety of tasks, is of several conventional and numeric controller types, the controllers can be: proportional integral (PI),PID, FLC or hybrid model like: Fuzzy-Neural Networks, Fuzzy-Genetic Algorithm, Fuzzy-Ant Colony, etc.[2].The major problems in applying conventional control algorithms (PI, PD, PID) in speed controller are the effects of non-linearity in a DC motor.FLC has evolved as an complementary to the conventional control strategies in various engineering areas. Unlike conventional control, designing a FLC does not require precise knowledge of the system model like the poles and zeroes of the system.FLC generally provides non-linear controllers that are capable of performing complex non-linear control action, even for uncertain nonlinear Systems.FLC is one of the most desired applications of fuzzy set theory, which is applied in an attempt to controlsystem that are structurally difficult to model.

II. DC MOTOR MATHEMATICAL MODELING

DC motors are most suitable for wide range speed control and are there for more adjustable speed drive. The equivalent circuit of DC motor is shown in fig 1[1].

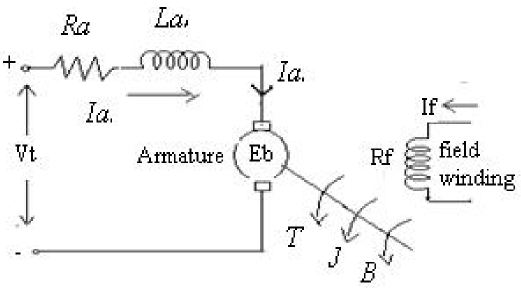

Fig. 1. The equivalent circuit of DC motor.

Where, R_a=Armature Resistance,

L_a=Armature self-inductance caused by armature flux,

I_a= Armature current,

I_f= field current,

E_b=Back EMF in armature,

V_t =Applied voltage,

T=Torque developed by the motor,

J =Equivalent moment of inertia of motor shaft & load referred to the motor,

B= Equivalent Coefficient of friction of motor shaft & load referred to the motor.

The transfer function of DC motor speed with respect to the input voltage can be written as follows:

$G(s)=\omega(s)/V(s)$

$=K_t/(R_a+sL_a)(Js+B)+K_bK_t$……….(1)

From the above given equation (1) the armature inductance value is very low in practices, hence the transfer function of dc motor speed to the input voltage can be simplified as follows,

$G(s)=\omega(s)/V(s)=K_m/\tau_s+1$…………(2)

Where Km is the motor gain and τ is the motor time constant. From equation (2) the transfer function can be drawn as the DC motor block diagram as shown in fig 2 and the Simulink model of the DC motor is shown in fig 3.

Field controlled dc motor is open loop while armature controlled is closed loop system. Hence armature controlled dc motor are preferred over field controlled system[1].

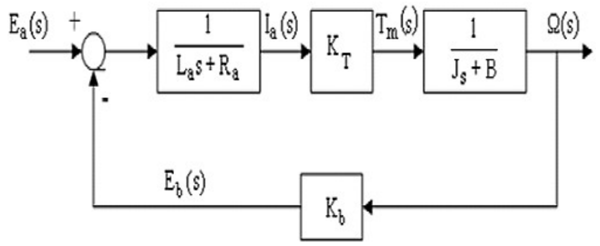

Fig. 2. Modeling block diagram of DC motor.

Table 1. DC MOTOR PARAMETERS.

Parameter	Description	Value
J	Moment of inertia	0.01
b	Viscous friction	0.1
K_t	Motor torque constant	0.01
K_b	Back emf constant	0.01
R_a	Electric resistance	1Ω
L_a	Electric Inductance	0.5H

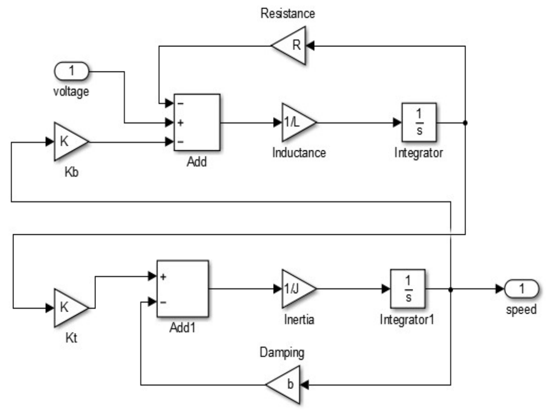

Fig. 3. Matlab/Simulink model for DC motor.

Speed control of the dc motor without any controller is shown in fig 4.

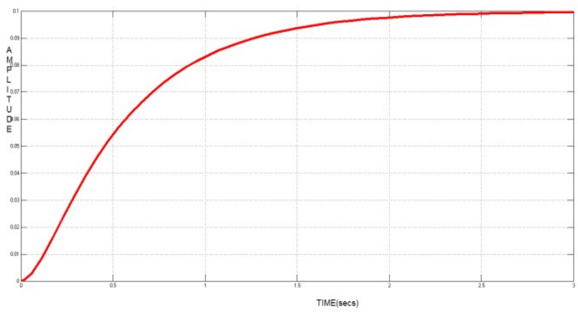

Fig. 4. Open loop step response of DC motor.

III. PID CONTROLLER

A PID controller is a control loop feedback mechanism as shown in fig 5. PID controller consists of three basic coefficients: proportional, integral and derivative which are varied to get optimal response. The controller attempts to minimize the error by adjusting the process control input.PID controllers are widely used in industrial control applications due to their simple structures, comprehensible control algorithms and low costs [4]. A PID controller and outputs a corrective action, which corrects the error between the process output and desired set point that adjust the process accordingly and rapidly[3].The step response of the PID controller is shown in fig 12 obtained from the Simulink model as shown in fig 6.

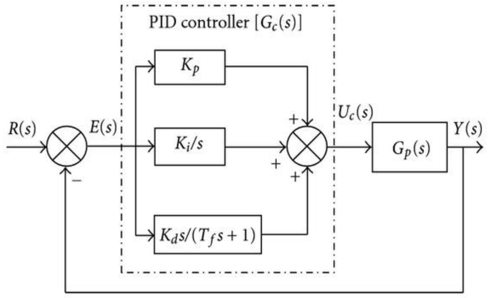

Fig. 5. Block diagram of PID controller system.

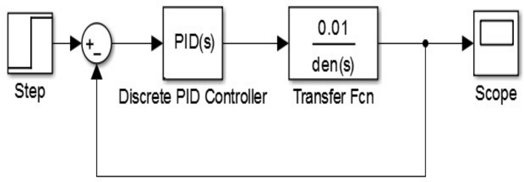

Fig. 6.MATLAB model of PID controller.

IV. FUZZYLOGIC CONTROLLER

Fuzzy control systems are knowledge-based or rule-based systems. The heart of a fuzzy system is a knowledge base consisting of the so-called fuzzy IF-THEN rules [2]. The fuzzy uses the IF-THEN rule which is an IF-THEN statement in which some words are characterized by continuous membership functions. Some words are characterized by continuous membership functions in a fuzzy If-Then statement.The fuzzy sets are defined after which the membership functions are assigned, rules must be written to describe the action to be taken for each combination of control variables. The written rules will relate the input variables to the output variable using If-Then statements which allow decisions to be made. If (condition) is an antecedent to the Then (conclusion) of each rule [2]. Each rule in general can be represented in the following manner: If (antecedent) Then (consequence).

For example: If the water tank is full, then closes the tap or If pressure is high, then volume is small.

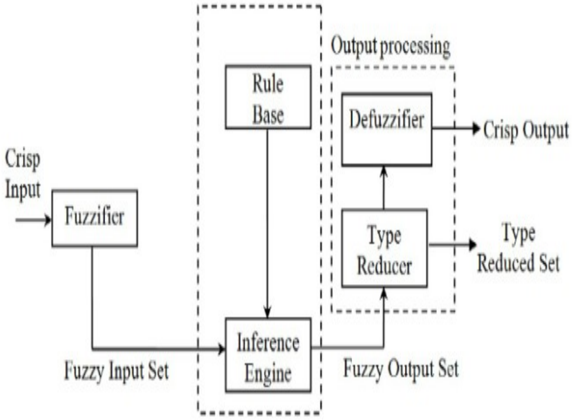

Fig. 7. Block diagram of FLC.

Fuzzy membership functions are used as tools to convert crisp values to linguistic terms as shown in table 2. A fuzzy membership function can contain several fuzzy sets depending on how many linguistic terms are used. Each fuzzy set represents one linguistic term [5].The simulink model of FLC is shown in fig 11.

Advantages of FLC include [6]:

- Inherent approximation capability.
- High degree of tolerance.
- Smooth operation.
- Reduce the effect of Non-linearity.
- Fast adaptation.
- Learning ability.

Table 2. FUZZY LINGUISTIC.

Term	Definition
NL	Negative large
NM	Negative medium
NS	Negative small
ZE	Zero
PS	Positive small
PM	Positive medium
PL	Positive large

The designers choose many different shapes based on their preference and experience in order to define fuzzy membership function, [5]. There are generally four types of membership functions used namely: Trapezoidal MF, Triangular MF, Gaussian MF and Generalized bell MF.

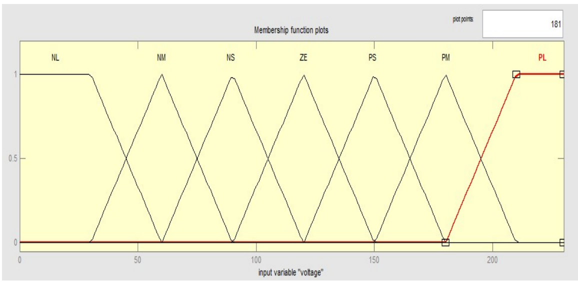

Fig. 8. Membership functions of input voltage.

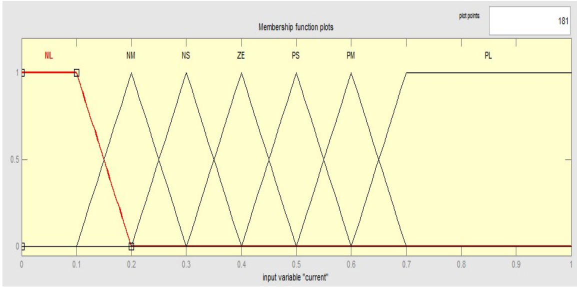

Fig. 9. Membership functions of input current.

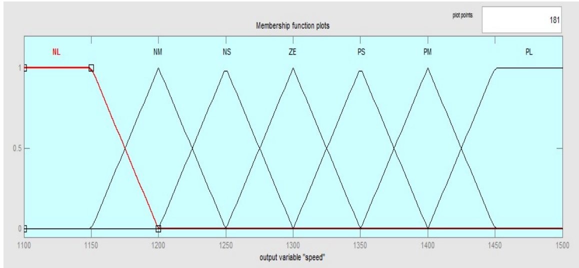

Fig. 10. Membership functions of output speed.

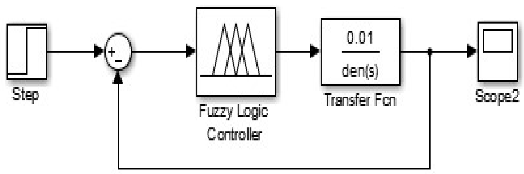

Fig. 11. MATLAB model of fuzzy logic controller.

V. RESULT

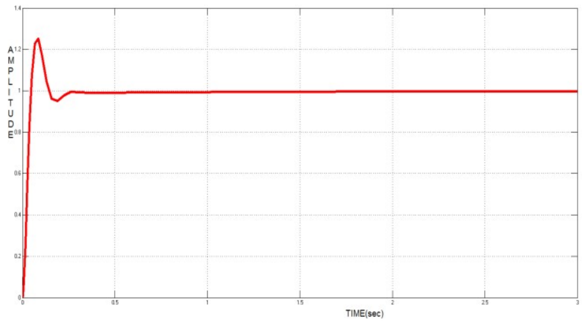

Fig. 12. Step response of PID controller.

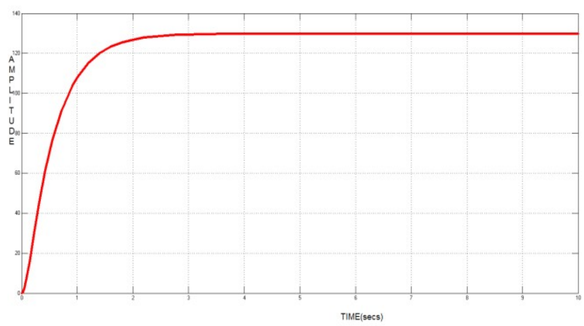

Fig. 13. Step response of FLC.

Comparison between both controllers gives the different output response as shown in fig 12 and 13. The FLC controller does not have the percentage overshoot but the PID controller has percentage overshoot. The settling time is the time that is taken from steady state, for this output response of the FLC is faster than PID controller.

VI. CONCLUSION

The FLC and PID controller was designed in MATLAB and the output was observed. In case of PID controller the output response depends on the value of proportional, integral and derivative due to which the desired output is not attained whereas in case of FLC, it has better performance than the conventional PID controller where the rules are set and fed to the model and more stable output is obtained. There is a wide range scope of applications of high performance DC motor in area such as rolling mills, chemical process, electric trains, robotic manipulators and the home electric appliances.

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