

# MODELLING AND ANALYSIS OF SELF-ADAPTIVE FUZZY-PID CONTROL TO SPEED REGULATING SYSTEM OF BLDC MOTOR

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**ABSTRACT-** The main objective of this paper is controlling the speed of DC motor when the load is varying. Various methods of speed control of DC motor is available. This paper presents design and implementation of Fuzzy Logic in the speed control of DC motor. Fuzzy logic has found high applications as a speed control techniques because of its ability to take into account vague and uncertainties. This paper presents a MATLAB simulink model for speed control of DC motor using fuzzy logic. In this paper used as the controller necessary signal conditioning components are used to ensure high processing speed and precision in the overall control system. The implemented system has a fast response with small overshoot and zero steady state error compared to conventional PI controller.

**Keywords:** DC Motor, Fuzzy logic controller.

## 1. INTRODUCTION

In spite of the development of power electronics resources, the direct current machine became more and more useful. Now a day's their uses isn't limited in the car applications (electric vehicle), in applications of weak power using battery system (motor of toy) or for the electric traction in the multi-machine systems too.

The speed of DC motor can be adjusted largely as to provide controllability easy and high performance. The controllers of the speed that are conceived for goal 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: PID Controller, Fuzzy Logic Controller; or the combination between them Fuzzy- Genetic Algorithm, Fuzzy-Neural Networks, Fuzzy-Ants Colony, Fuzzy-Swarm (Swarm). Fuzzy theory was first proposed and investigated by Prof. Zadeh in 1965. The Mamdani fuzzy inference system was presented to control a steam engine and boiler combination by linguistic rules. Fuzzy logic is expressed by means of if-then rules with the human language. In the design of a fuzzy logic controller, the mathematical model is not necessary. Thus, the fuzzy logic controller owns good robustness. Fuzzy controller has been widely used in industry for its easy realization. However, the rules and the membership functions of a fuzzy logic controller are constructed by expert experience or knowledge database.

## 2. MODELING OF DC MOTOR

A common actuator in control systems is the DC motor. It directly provides rotary motion and, coupled with wheels or drums and cables, can provide translational motion. The electric circuit of the armature and the free-body diagram of the rotor are shown in the following Fig.1:

For this example, we will assume that the input of the system is the voltage source ( $V$ ) applied to the motor's armature, while the output is the rotational speed of the shaft  $d(\theta)/dt$ . The rotor and shaft are assumed to be rigid. We further assume a viscous friction model, that is, the friction torque is proportional to shaft angular velocity[1].

The physical parameters for our example are: Parameter Value

- R-resistance  $1 \Omega$
- L-inductance  $29.79 \text{ mH}$
- J-moment of inertia  $0.01 \text{ kg.m}^2$
- $K_t$ -torque constant  $0.052 \text{ Nm/A}$
- $K_b$ -electromotive force constant  $0.1 \text{ V/rad/s}$
- B-viscous friction coefficient  $0.004 \text{ N.m/rad/s}$

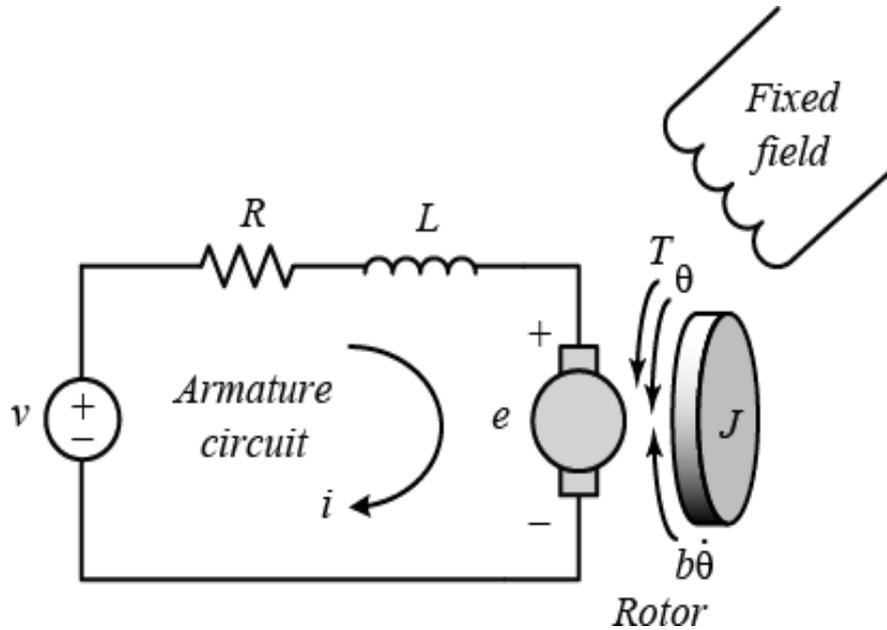


Fig. 1. separately excited dc motor

In general, the torque generated by a DC motor is proportional to the armature current and the strength of the magnetic field. In this example we will assume that the magnetic field is constant and, therefore, that the motor torque is proportional to only the armature current  $i$  by a constant factor  $Kt$  as shown in the equation below.

This is referred to as an armature-controlled motor[2].

Here, the differential equation of armature circuit is-

$$E_a(t) = R_a I_a(t) + L_a \frac{di_a(t)}{dt} + E_b(t) \quad (1)$$

The Torque equation is-

$$T_m(t) = J \frac{d\omega_m(t)}{dt} + B \cdot \omega_m(t) \quad (2)$$

The torque developed by motor is proportional to the product of the armature current and field current i.e.

$$T_m(t) = k_f i_f i_a \quad (3)$$

Where,  $K_f$  is the constant. In armature-controlled D.C motor the field current ( $i_f$ ) is kept constant i.e.

$$T_m = K_T \cdot i_a \quad (4)$$

Where,  $K_T = K_f \cdot i_f$  is torque constant. The back e.m.f. of motor is proportional to the speed i.e.

$$E_b(t) = K_b \cdot \omega_m \quad (5)$$

Where,  $K_b$  is back e.m.f. constant. In order to create the block diagram of system initial conditions are zero and Laplace transform is implemented to the equation. i.e.

$$E_a(s) = R_a \cdot I_a(s) + s L_a \cdot I_a(s) + E_b(s)$$

$$I_a(s) = \frac{E_a(s) - E_b(s)}{s L_a + R_a} \quad (6)$$

$$T_m(s) = sJ \cdot \omega_m(s) + B \cdot \omega_m(s)$$

$$\omega_m(s) = \frac{T_m(s)}{sJ + B} \quad (7)$$

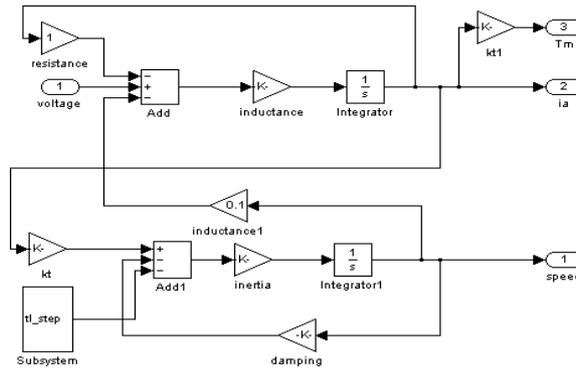
$$T_m(s) = K_T \cdot i_a(s) \quad (8)$$

$$E_b(s) = k_b \cdot \omega_m(s) \quad (9)$$

The angular acceleration is equal to  $1/J$  multiplied by the sum of two terms (one positive, one negative). Similarly, the derivative of current is equal to  $1/L$  multiplied by the sum of three terms (one positive, two negative). The final design should look like the example shown in the figure below. The following Fig.2. shows the modeling of DC motor, which is obtained from the above mathematical analysis using MATLAB/Simulink[9].

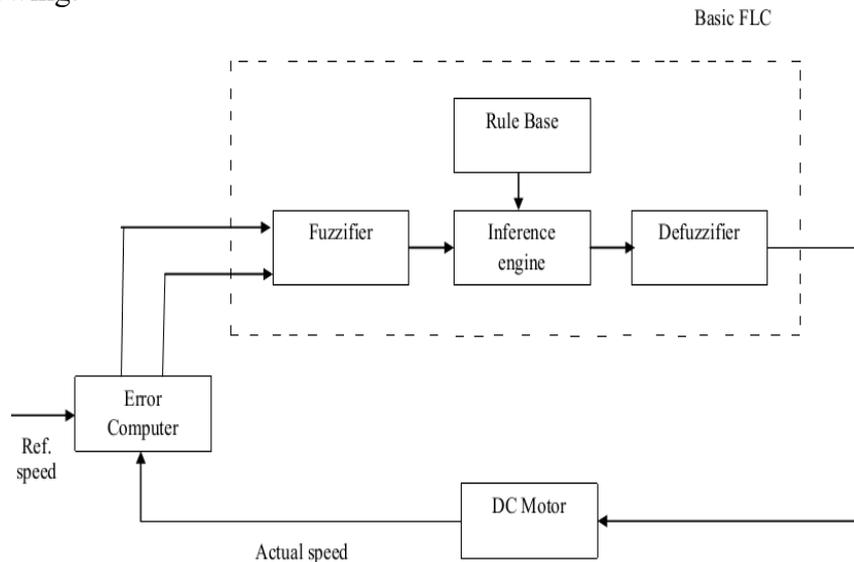
### 3. FUZZY LOGIC CONTROLLER

#### 3.1. Block diagram and its description



**Fig. 2. modeling of dc motor**

Fuzzy logic control is a control algorithm based on a linguistic control strategy, which is derived from expert knowledge into an automatic control strategy. Fuzzy logic control doesn't need any difficult mathematical calculation like the others control system. While the others control system use difficult mathematical calculation to provide a model of the controlled plant, it only uses simple mathematical calculation to simulate the expert knowledge. Although it doesn't need any difficult mathematical calculation, but it can give good performance in a control system. Thus, it can be one of the best available answers today for a broad class of challenging controls problems. A fuzzy logic control usually consists of the following:



**Fig. 3.basic block diagram for FLC**

3.2. Design procedure for fuzzy logic controller

The Fuzzy Logic Controller is a seven step procedure to control the speed of a DC motor. Those steps are mentioned in the following Fig.4.

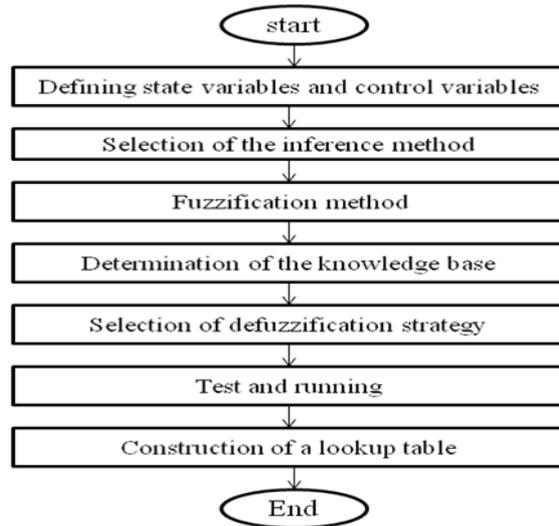


Fig. 4. flow chart for FLC

3.3. Simulink Model for FLC

The fuzzy logic controller for speed controller for DC motor was implemented in MATLAB/Simulink. Block diagram show the simulation model[9].

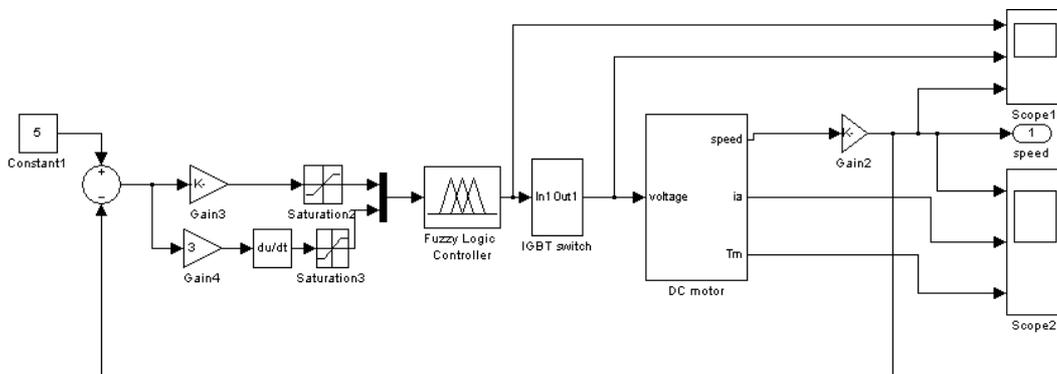


Fig. 5. modeling of fuzzy logic controller

The above fuzzy logic controller modeling has two subsystems. One is DC motor, which shows Fig.2. And another is IGBT switch, shown in the following Fig.6.

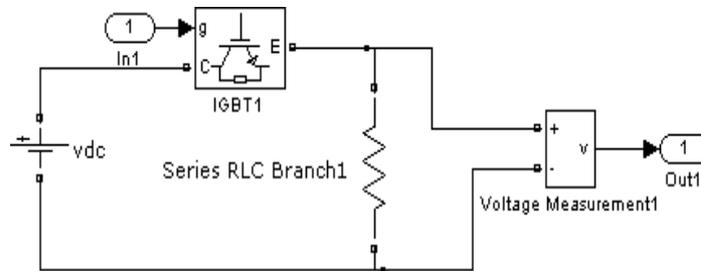


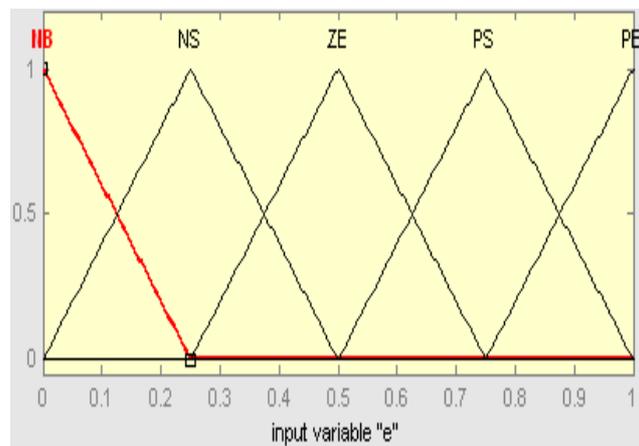
Fig. 6. modeling for IGBT switch

3.4. Fuzzy Controller Design

The most important things in fuzzy logic control system designs are the process design of membership functions for inputs, outputs and the process design of fuzzy if-then rule knowledge base [2]. They are very important in fuzzy logic control. The basic structure of Fuzzy Logic Controller is given in Fig.5. For the D.C. drive, speed error (e) and change in speed error (ce) are taken as the two inputs for the fuzzy controller and one output (z) . For this, a two-member as well as a five-member rule base is devised. The rule base for five membership functions is shown in TableI.

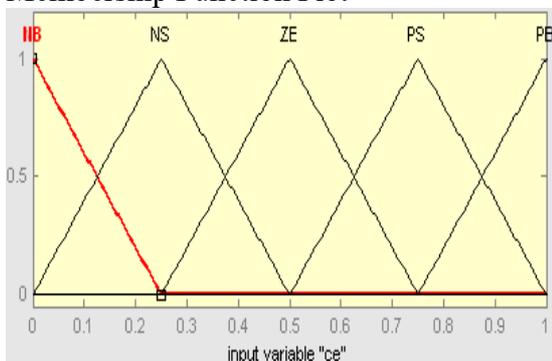
|    |    |    |    |    |    |
|----|----|----|----|----|----|
| E  | NB | NS | ZE | PS | PB |
| CE | NB | NS | ZE | PS | PB |
| NB | NB | NS | ZE | PS | PB |
| NS | NB | NS | ZE | PS | PB |
| ZE | NB | NS | ZE | PS | PB |
| PS | NB | NS | ZE | PS | PB |
| PB | NB | NS | ZE | PS | PB |

Table I Rule Base for FLC

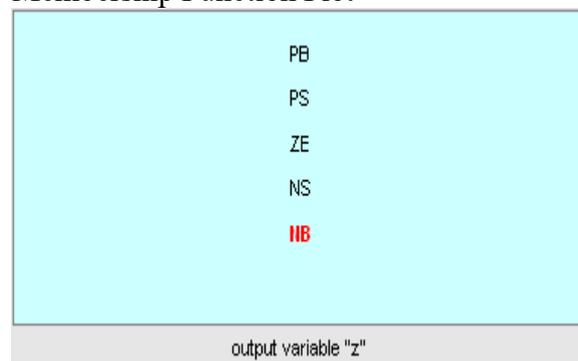


Membership Function Plot 7(a). input1 (e)

Membership Function Plot



Membership Function Plot



**7(b). input 2 (ce)**

**7(c). output (z)  
ship functions of e, ce, and z in normalized plot**

In this paper as mentioned in Table1,it consist of two input variables(e & ce), one out variable (z), and five linguistic variables {NB,NS,ZE,PS,PB} described in TABLE II.so that here we can have 25 (no.of linguistic variables ^ no.of input variables =  $5^2 = 25$ ) rules totally. As mentioned in fig.5,we can plot the membership functions for both inputs and outputs. Here TSK(Takagi Sugino Kang) method was used to plot the membership function.

**Table II Linguistic Variables Description**

|    |                      |
|----|----------------------|
| NB | NEGATIVE BIG VALUE   |
| NS | NEGATIVE SMALL VALUE |
| ZE | ZERO VALUE           |
| PS | POSITIVE SMALL VALUE |
| PB | POSITIVE BIG VALUE   |

3.5. Rule View and Surface View

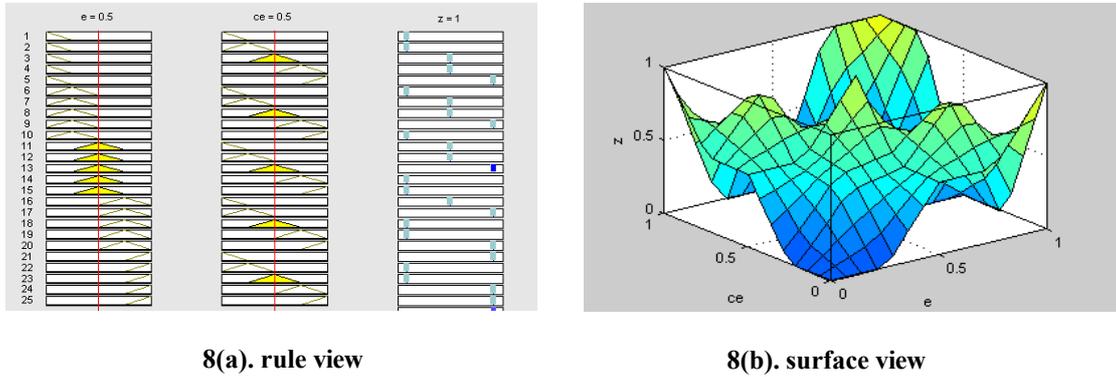


Fig. 8. rule view and surface view of flc

4. SIMULATION RESULTS

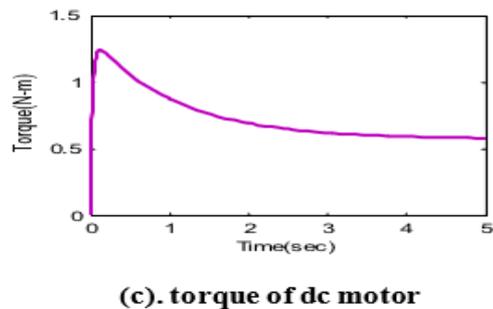
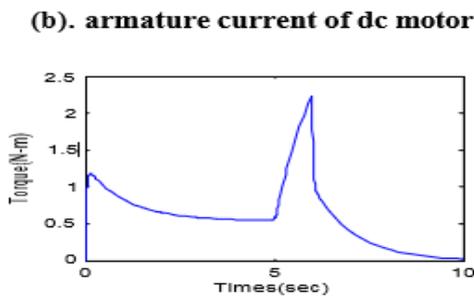
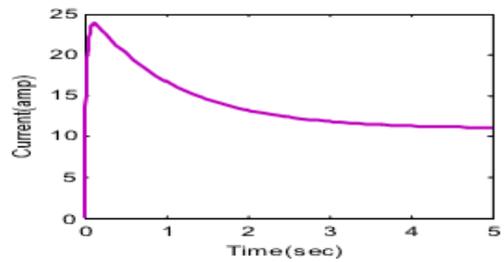
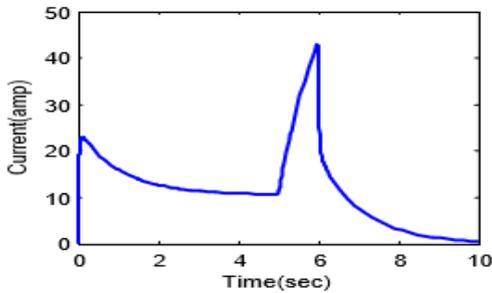
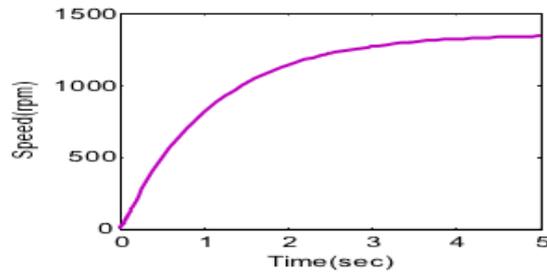
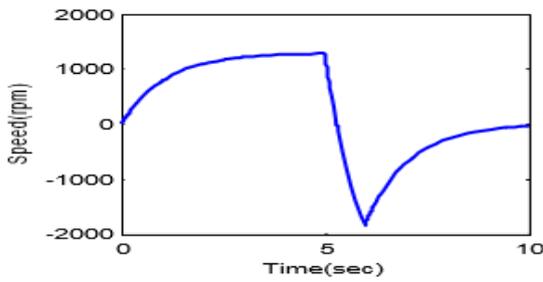


Fig. 9. speed, current & torque comparison of dc motor before applied to the flc

Fig. 10. speed, current & torque comparison of dc motor after applied to the flc

## 5. CONCLUSION

A fuzzy logic based controller for a D.C. servomotor has been studied. The design of the fuzzy logic controller has been explained and the performance was evaluated by simulation. The results show significant improvement in speed. The above results show the comparison between speed of the dc motor before applied to the Fuzzy Logic Controller, which is shown in the above Fig.2. and speed of the dc motor after applied to the Fuzzy Logic Controller, shown in Fig.5. The Fig.9. shows the results for the simulink block diagram of Fig.2. and Fig.10. shows the results for the simulink block diagram of Fig.5. By comparing Fig.9 & 10, Fig.10. has the better speed, current and torque response. So we can say FLC is a better speed controller.

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