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A Novel Approach to Control speed of Brushless DC Motor using Fuzzy Logic Controller

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Abstract – **DC drive systems are often used in many industrial applications such as robotics, actuation and manipulators. The purpose of this research work is to control the speed of Brushless DC (BLDC) motor by using fuzzy logic controller (FLC) in MATLAB / SIMULINK model. The scopes includes the modelling and simulation of Brushless DC motor, application of fuzzy logic controller to actual DC motor and to compare with the Proportion Integral (PI) Controller model. This examination is going to present the new capacity of assessing speed and control of the Brushless DC motor. By utilizing the FL controller, the rate can be tuned until it get like the desired output that a user wants.**

Keywords – **Brushless DC motor, Fuzzy Logic Controller, PI Controller MATLAB.**

I. INTRODUCTION

The direct current (DC) motor is a gadget that utilized as a part of numerous businesses so as to change the characteristic of electrical energy into mechanical energy [3]. This is all result from the availability of speed controllers is wide range, easily and many ways. In most applications, speed control is very important. For example, if we have DC motor in radio controller car [2], in the event that we simply apply a static power to the motor, it is impossible to maintain the desired speed. It will go slower over rocky road, slower uphill, faster downhill and so on. In this way, it is imperative to make a controller to control the speed of DC motor in wanted speed.

DC motor assumes a huge part in present day industry. The motivation behind a motor speed controller is to take a sign speaking to the requested speed, and to drive a motor at that speed. There are numerous applications where control of speed is required, as in rolling mills, cranes, hoists, elevators, machine tools, transit system and locomotive drives. Usages stated above may request fast control exactness and great element reactions [6].

There are some issue happen while controlling the DC motor, the issue happen, for example, misfortunes and productivity of the motor [7]. To experience the issue, the controller is required and for this research, Fuzzy Logic Controller is utilized. There are too many controllers nowadays but FLC is chosen to interface with the DC motor because it suitable for application which has nonlinearities such speed of the DC motor. Either than that, it has several advantages such as low cost and simplicity of control [8] [9].

At the most essential level, electric motors exist to change over electrical energy into mechanical energy. This is carried out by method for two communicating magnetic fields – one stationary, and an alternate connected to a part that can move. Various sorts of electric motors exist, however for the most part utilized DC motors within some structure or an alternate. DC motors have the potential for high torque abilities (despite the fact that this is for the most part a capacity of the physical size of the motor), are not difficult to scale down, and can be "throttled" through conforming their supply voltage. DC motors are additionally the least difficult, as well as the most established electric motors [4].

The goal of this paper is to execute a control strategy utilizing fuzzy logic controller which is utilized to create a control signal for speed control of Brushless DC Motor.

II. MODELLING OF BRUSHLESS DC MOTORS

In any electric motor, operation is focused around basic electromagnetism. A current convey conductor creates an magnetic field; when this is then put in an outer magnetic field, it will encounter an energy corresponding to the present in the conductor, and to the quality of the outside magnetic field. As we are well mindful of from playing with magnets as a child, inverse (North and South) polarities pull in, while like polarities (North and North, South and South) repulse. The inner design of a DC motor is intended to saddle the magnetic communication between a current convey conductor and an outer magnetic field to produce rotational movement.

Brushless DC motors are to a great degree attractively as they totally dispense with the requirement for brushes. This builds their life, survival without support, power yield and effectiveness severely [11].

Their fundamental working rule is to encourage an outer commutator, which will switch the course of the current relying upon the position of the rotor.

As there are no brushes, support levels are brought down significantly, and as there is no grinding created by brushes, the productivity of a brushless motor is commonly somewhere around 85 and 90 percent (a brushed motor's effectiveness is typically around 75 to 80 %). This makes them perfect for overwhelming obligation utilize, and cost effectiveness in the long haul. They likewise run much cooler than AC and brushed motors, which incredibly expands the life of the motors in connection.

Brushless DC motors have the field coil in parallel (Brushless) with the armature. The current in the armature and field coil are free of each other. Therefore, these motors have fabulous speed and position control. Henceforth BLDC motors are commonly utilized that oblige five or more HPs (Horse Power). The equations depicting the vibrant performance of the BLDC motor are given as under.

$$v = Ri + L\frac{di}{dt} + e_b \quad (1)$$

$$T_m = K_T i_a(t) \quad (2)$$

$$T_m = J\frac{d^2\theta(t)}{dt^2} + B\frac{d\theta(t)}{dt} \quad (3)$$

$$eb = e_b(t) = K_b\frac{d\theta(t)}{dt} \quad (4)$$

Where, R = Armature resistance in ohm.
L = Armature inductance in henry.
$i = i_a$ = Armature current in ampere.
v = Armature voltage in volts.
eb = Back EMF voltage in volts.
K_b = Back EMF constant in volt / (rad/sec).
K_T = Torque constant in N-m/Ampere,
T_m = Torque developed by the motor in N-m.
$\theta(t)$ = Angular displacement of shaft in radians,
J = Moment of inertia of motor and load in Kg-m2/rad.
B = Frictional constant of motor and load in N-m / (rad/sec).

On the basis of the equations stated above, we realized a MATLAB/SIMULINK model for the brushless DC motor as shown in figure 1.

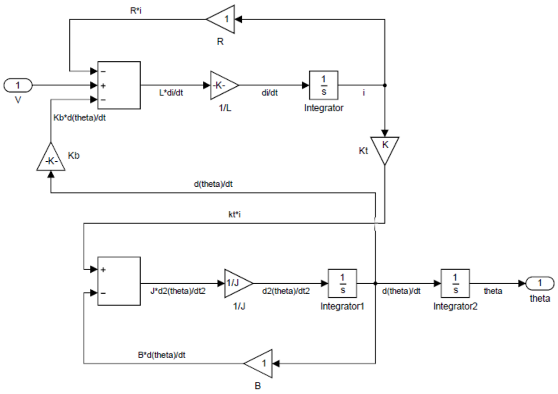


Figure 1: Simulink model for brushless DC motor

III. PROPOSED METHODOLOGY

Figure 2 and Figure 3 exhibit the basic block diagrams for proposed methodology.

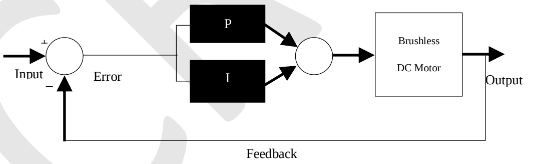


Figure 2: Schematic diagram for speed control of brushless DC motor based on PI Controller

PI controller consists of proportional action and integral action. It is commonly refer to Ziegler-Nichols PI tuning parameters. It is by far the most common control algorithm. PI controller's algorithm are mostly used in feedback loops. PI controllers can be implemented in many forms. It is interesting to note that more than half of the industrial controllers in use today utilize PI or modified PI control schemes. A diagram illustrating the schematic of the PI controller is illustrated in figure 2. Such setup is known as non-interacting form or parallel form.

In proportional control,

$$\mathrm{P_{term}} = \mathrm{K_P} * \mathrm{Error} \quad (5)$$

It uses proportion of the system error to control the system. In this action an offset is introduced in the system.

In Integral control,

$$\mathrm{I_{term}} = \mathrm{K_I} * \int \mathrm{Error}\ dt \quad (6)$$

It is proportional to the amount of error in the system. In this action, the I-action will introduce a lag in the system. This will eliminate the offset that was introduced earlier on by the P-action.

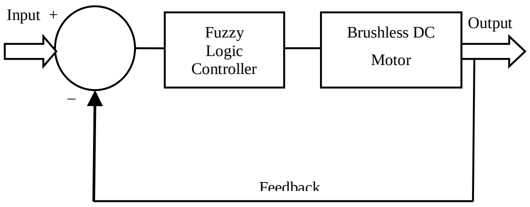


Figure 3: Schematic diagram for speed control of brushless DC motor based on Fuzzy Logic Controller

While operating in a closed loop frameworks, a fuzzy controller plays a vital role. Transfer performance of fuzzy controller shows an important prominence, which is analyzed using different configurations of standard membership functions [5].

A fuzzy controller can be taken care of as a framework that transmits data like an ordinary controller with inputs containing data about the motor to be controlled and a yield that is controlled variable [10]. From outside, there is no uncertain data watched. Both the outcome and data qualities are fresh values. The data estimations of a fuzzy controller contain measured qualities from the motor that are either motor output values or states of motor, or control errors coming about because of the set point qualities and the controlled variables.

The Fuzzy logic (FL) joins a basic, standard based IF X AND Y THEN Z methodology to a tackling control issue as opposed to endeavoring to model a framework numerically. The FL model is exactly based, contingent upon an administrator's experience instead of their specialized understanding of the framework [11]. FL needs some numerical parameters to work, for example, what is viewed as huge error and noteworthy rate of progress of errors, however the precise estimations of these numbers are generally not discriminating unless extremely responsive execution is needed in which case observational tuning [1] would focus them.

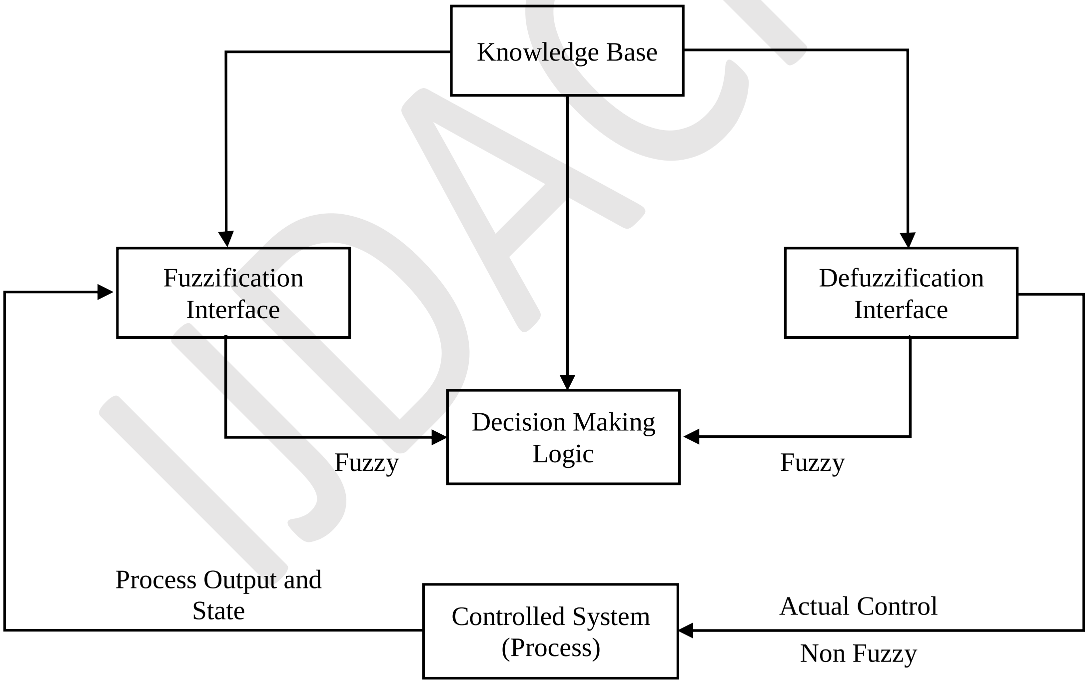


Figure 4: Basic Configuration of FLC [12]

The *Steps of Fuzzy Logic*

1. Delimit the control criteria and destinations.
2. Regulate the information and outcome connections and pick a base number of variables for data to the FL engine (regularly error and rate of progress of error).
3. Using the standard based structure of FL, separate the control exertion into an arrangement of IF X AND Y THEN Z chooses that characterize the fancied framework outcome reaction for anticipated framework information circumstances. The number and intricacy of principles rely on upon the quantity of data parameters that are

to be handled and the number fuzzy variables connected with every parameter. On the off chance that possible, use no less than one variable and now is the ideal time subordinate. Despite the fact that it is conceivable to utilize a solitary, fast error parameter without knowing its rate of progress, this invalids the framework's ability to lessening overshoot for a step inputs.

4. Generate FL membership functions that characterize the importance (qualities) of Input / Output terms utilized as a part of the principles.
5. Generate the essential pre and post processing FL schedules if executed in programming, or else program the principles into the FL hardware engine.
6. Examine the framework, ascertain the results, tune the membership functions & rules, and retest until suitable results are accomplished.

IV. SIMULATION AND RESULTS

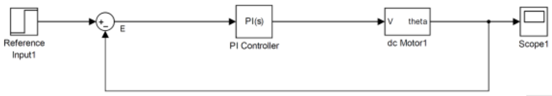


Figure 5: Simulink model for DC Motor controlled by PI controller

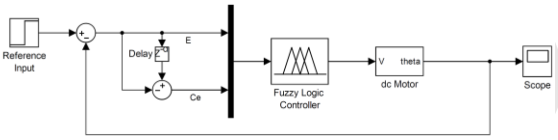
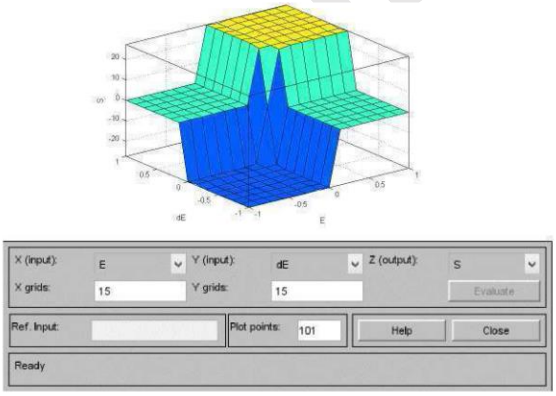


Figure 6: Simulink model for DC Motor controlled by Fuzzy Logic controller



X (input): E
Y (input): dE
Z (output): S
X grids: 15
Y grids: 15
Ref. Input:
Plot points: 101
Ready

Figure 7: Fuzzy surface of controller

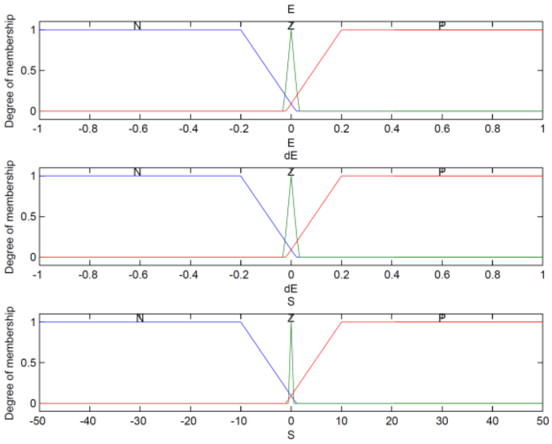


Figure 8: Membership function for fuzzy controller

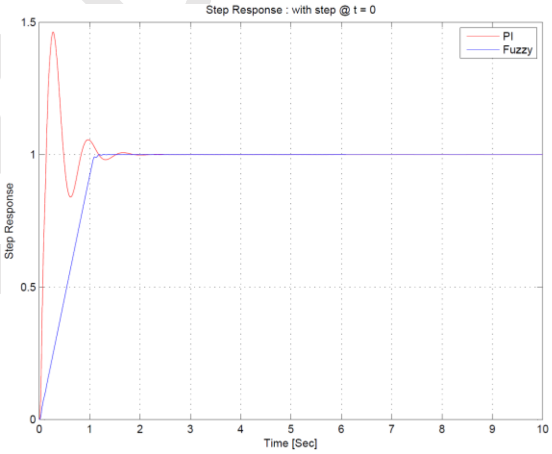


Figure 9: Comparison of step response of DC motor for PI controller and Fuzzy logic controller

Table 1: Comparison of step response values for PI controller and Fuzzy logic controller

	PI Controller	**Fuzzy logic Controller**
RiseTime	0.0944	0.8622
SettlingTime	1.1194	1.0715
SettlingMin	0.8394	0.9000
SettlingMax	1.4624	1.0010
Overshoot	46.2372	0.0995
Undershoot	0	0
Peak	1.4624	1.0010
PeakTime	0.2750	1.2860

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Table 2: Parameters of motor

Armature Resistance (Ra in ohms)	2.45
Armature Inductance La (H)	0.035
Inertia J (Kg*M^2/rad)	0.22
Frictional Constant B (N-M/rad/sec)	0.5e-3
Torque Constant K (N-M/Amp)	1.2
BLDC Motor Transfer Function	num = K; den = [J*La ((Ra*J) + (B*La)) ((K^2)+(Ra*B)) 0]

V. CONCLUSION

This paper proposes a model for speed control of brushless DC motor drive using Proportional Integral (PI) controller and Fuzzy Logic Controller (FLC). Simulation results show a comparison of step response values for PI controller and Fuzzy logic controller. The speed of a separately excited BLDC Motor has been successfully controlled by using fuzzy logic controller technique. It was found that the fuzzy logic controller gives better results rather than the PI controller.

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