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Speed Control of Brushless DC Motor using Fuzzy and Neuro Fuzzy

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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 paper is to control the speed of Brushless DC (BLDC) motor by using Fuzzy logic controller (FLC) and Neuro-fuzzy controller in MATLAB / SIMULINK model. The scopes includes the modelling and simulation of Brushless DC motor, application of fuzzy logic controller to actual DC motor. This paper is going to present the new capacity of assessing speed and control of the Brushless DC motor. By utilizing the Neuro-fuzzy 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 design a control scheme using fuzzy logic controller (FLC) and Neuro-Fuzzy controller which are used to generate a control signal for speed control of Brushless DC Motor. Additionally, BLDC motor step responses are also compared for the fuzzy logic controller (FLC) and Neuro-Fuzzy controller.

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.

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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.

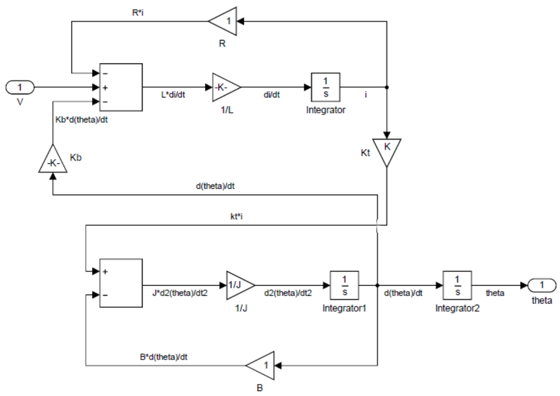

Figure 1: Simulink model for brushless DC motor

III. Proposed Methodology

Fuzzy Logic Controller

Figure 2 exhibits the basic block diagram for proposed Fuzzy logic controller based BLDC motor speed control system.

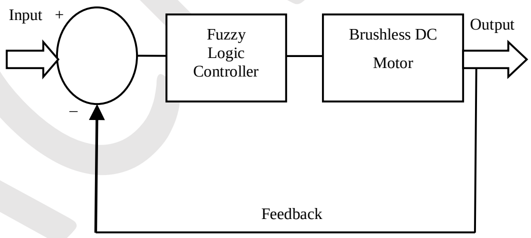

Figure 2: Basic block diagram for proposed Fuzzy logic controller based BLDC motor speed control system

A fuzzy controller is a superior fuzzy framework that can be utilized as a controller part within a closed loop framework. In a fuzzy framework incorporated with a closed loop, unique accentuation is put onto the exchange conduct of fuzzy controllers, which is dissected utilizing distinctive arrangements of standard membership functions.

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. 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.

Neuro-Fuzzy Controller

Figure 4.3 exhibits the basic block diagram for proposed Neuro fuzzy controller based BLDC motor speed control system.

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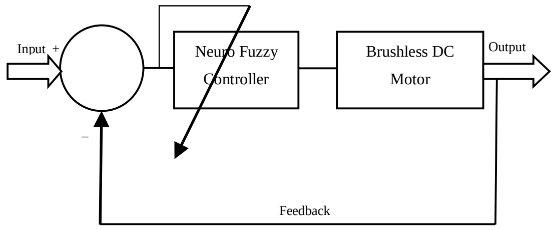

Figure 3: Basic block diagram for proposed Neuro fuzzy controller based BLDC motor speed control system

To get the favorable circumstances of fuzzy and neural networks and to beat their limitations, it is wised to utilize the mixture of both, which prompts Neuro-Fuzzy Controllers (NFC). The on-line supervised learning algorithm performs exceptionally well when the training information are accessible on-line. The error between the reference and BLDC motor output is utilized to change the weights. This controller is an Adaptive Network-based Fuzzy Inference System (ANFIS) [19].

Supervisory Learning in ANFIS

In a few circumstances it might be interesting to outline an automatic controller, which emulates the activity of the human. This has been called supervised control. A Neural Network gives one opportunity to this. Training the network is comparative on a fundamental level to taking in a system forward model. For this situation, then again, the system information compares to the sensory input data got by the human. The network target outcomes utilized for training relate to the human control input to the framework. Figure 4 demonstrates the NFC as a supervisory controller.

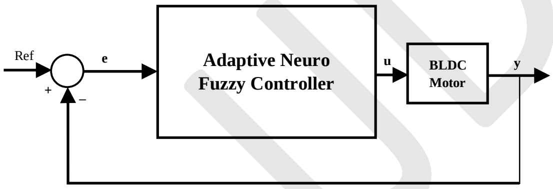

Figure 4: Supervisory Controller

IV. Simulation and Results

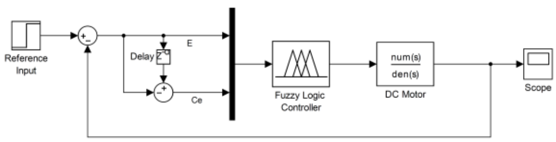

Figure 5: Simulink model for DC Motor controlled by Fuzzy Logic controller

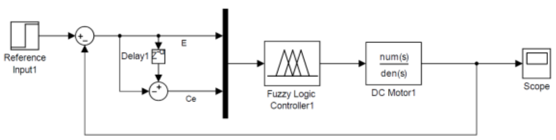

Figure 6: Simulink model for DC Motor controlled by Neuro-Fuzzy controller

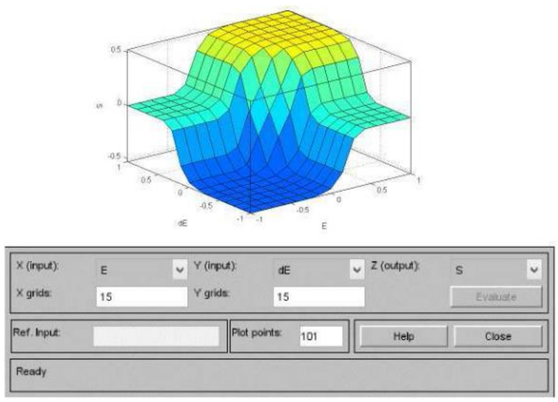

Figure 7: Fuzzy surface of controller

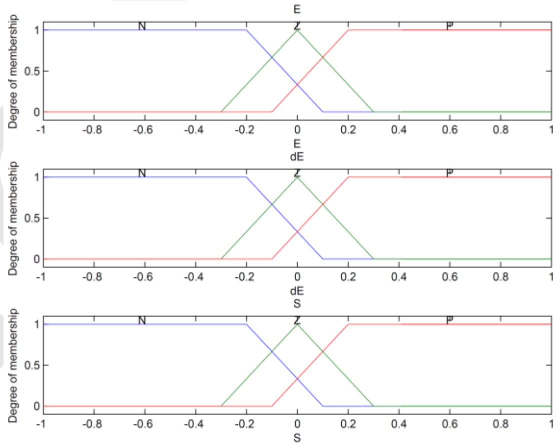

Figure 8: Membership function for fuzzy controller

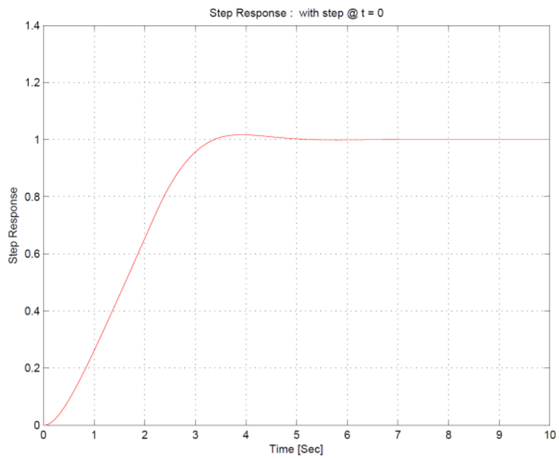

Figure 9: Step response of BLDC motor with Fuzzy Logic Controller

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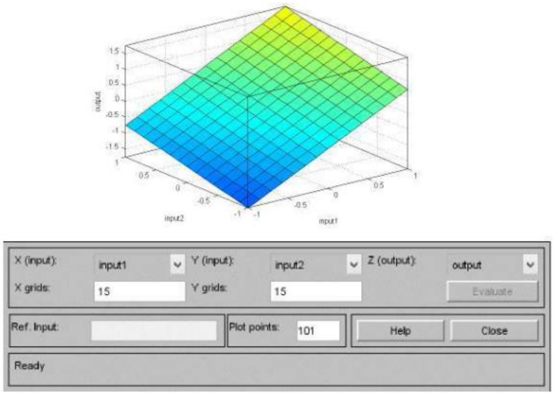

Figure 10: Fuzzy surface of Neuro-Fuzzy controller

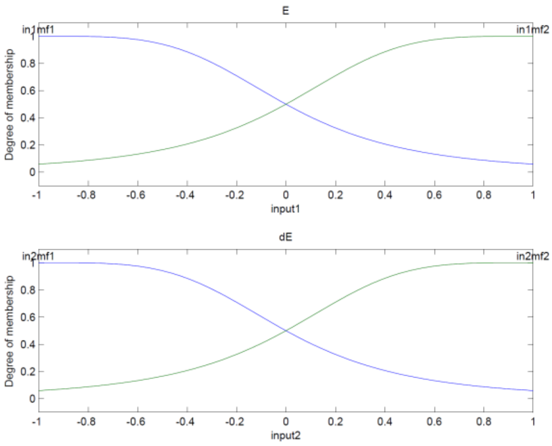

Figure 11: Membership function for Neuro-Fuzzy controller

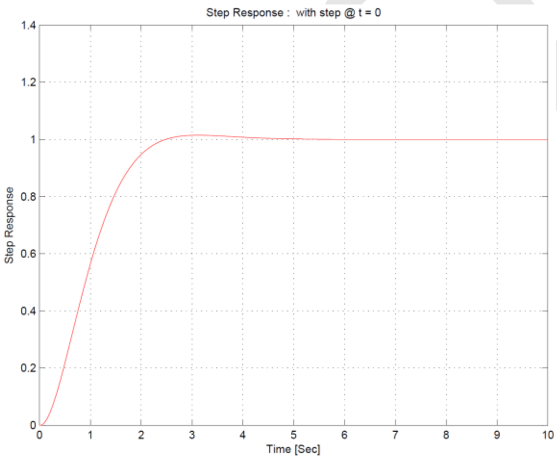

Figure 12: Step response of BLDC motor with Neuro-Fuzzy Controller

Table 1: Comparison of step response values for Fuzzy logic controller and Neuro-Fuzzy Controller

	Fuzzy Logic Controller	Neuro-Fuzzy Controller
RiseTime	2.1791	1.4602
SettlingTime	3.1683	2.2430
SettlingMin	0.9000	0.9002
SettlingMax	1.0170	1.0142
Overshoot	1.7016	1.4205
Undershoot	0	0
Peak	1.0170	1.0142
PeakTime	3.9130	3.1230

V. Conclusion

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

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