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Performance Analysis and Implementation of Brushless DC Motor by PID, Fuzzy and ANIFS Controllers

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Abstract: Now a day's Brushless DC (BLDC) motors are more popular because of its good electrical and mechanical property. These motors are now changing to brushed DC motors and induction motors in various applications. The main problem that occurs in the traditional PID controller is that the parameters obtained from the drive control system of the BLDC servo motor cannot produce a steady state under various operating conditions such as adjusted gain plus transient response and parameter variation, load disturbance. So a fuzzy controller provides good speed response for start-up.

In this paper how the design and simulation of ANFIS controller is better for the performance of brushless DC motor (BLDC) servomotor as well as the design and implementation of ANFIS controller and its performance are compared is shown. The capability of BLDC servomotor based on Fuzzy, ANFIS and PID controller is investigated under different operating conditions. Paper represents the PID controller and fuzzy controller to demonstrate error tracking capability and usefulness of ANFIS controller in control applications. By using the PID, Fuzzy and ANFIS controller we can implement, analyze the overall performance of brushless DC motor.

KEYWORDS:
Proportional-Integral-Derivative (PID) controller, Brushless DC (BLDC) motor, Adaptive-Network-Based Fuzzy Inference System (ANFIS), (FLC) Fuzzy logic controller (IGBT) Insulated Gate Bipolar Transistor.

INTRODUCTION:

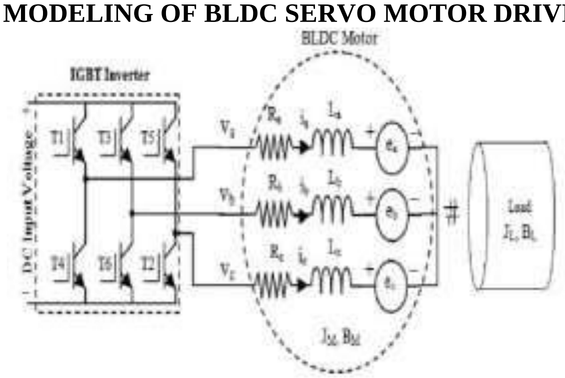
The brushless DC motor is widely used in industrial application for its different advantage over other conventional motor such as better, speed and torque characteristics, better dynamic response, high efficiency ,high speed range, no noise operation and high weight to torque ratio. Unlike the conventional DC motors, brushless DC motors do not have brushes. So, the commutation takes place electronically, unlike with brushes in conventional DC motors.

The Brushless Direct Current motor is the ideal choice for applications that require high reliability, high efficiency, and high power to volume ratio. Generally speaking, a BLDC motor is considered to be a high performance motor that is capable of providing large amounts of torque over a vast speed range.

BLDC motors do not have brushes and must be electronically commutated. Commutation is the act of changing the motor phase currents at the appropriate times to produce rotational torque. In a brush DC motor, the motor assembly contains a physical commutator which is moved by means of actual brushes in order to move the rotor. With a BLDC motor, electrical current powers a permanent magnet that causes the

motor to move, so no physical commutato ris necessary. A BLDC motor is highly reliable since it does not have any brushes to wear out and replace.
The PID controllers have the capability of eliminating steady state error due to integral action and can anticipate output changes due to derivative action when the system is subjected to a step reference input. Fuzzy logic is a type of estimated number of reasons that evaluate the reality of variables can be any genuine numbers around 0 and 1. Adaptive system of neuro-fuzzy inference (ANFIS) refers in general to an adaptation network that performs the function of the system of inference fuzzy. The most commonly used ANFIS fuzzy system architecture model is Sugeno since it is less computational and more transparent than other models. The serial membership function of the model (MF) Sugeno can be parameterized by any arbitrary function of neat entries is likely polynomial.

MODELING OF BLDC SERVO MOTOR DRIVE SYSTEM:



The equivalent circuit of the BLDC servomotor drive system is shown in Fig.1
The line to line voltage equations are expressed in matrix form as

$$\begin{bmatrix} V_{\mathrm{ab}} \\ V_{\mathrm{bc}} \\ V_{\mathrm{ca}} \end{bmatrix} = \begin{bmatrix} R & -R & 0 \\ 0 & R & -R \\ -R & 0 & R \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + \begin{bmatrix} L-M & M-L & 0 \\ 0 & L-M & M-L \\ M-L & 0 & L-M \end{bmatrix} \times \frac{di}{dt} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + \begin{bmatrix} e_a - e_b \\ e_b - e_c \\ e_c - e_a \end{bmatrix}.$$

Since the mutual inductance is negligible as compared to the self-inductance, the aforementioned matrix equation can be rewritten as

$$\begin{bmatrix} V_{\mathrm{ab}} \\ V_{\mathrm{bc}} \\ V_{\mathrm{ca}} \end{bmatrix} = \begin{bmatrix} R & -R & 0 \\ 0 & R & -R \\ -R & 0 & R \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + \begin{bmatrix} L & -L & 0 \\ 0 & L & -L \\ -L & 0 & L \end{bmatrix} \times \frac{di}{dt} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + \begin{bmatrix} e_a - e_b \\ e_b - e_c \\ e_c - e_a \end{bmatrix}$$

Where, L and M are self-inductance and mutual inductance per phase; R is the stator winding resistance per phase; ea, eb and ec are the back EMFs of phases *a*, *b*, and *c*, respectively; ia, ib ,and ic are the phase currents of phases *a*, *b*, and *c*, respectively. The electromagnetic torque developed by the motor can be expressed as $Te = (ea\ ia + eb\ ib + ec\ ic)/\omega = KtI$
The output power developed by the motor is $P = Te\omega$

DESIGN AND IMPLEMENTATION OF PID CONTROLLER:
The continuous control signal u(t) of the PID controller is given by u(t) = Kp (e (t) +(1/Ti) ∫ e (t)dt +Td de (t)/dt) where, Kp is the proportional gain, Ti is the integral time constant, Td is the derivative time constant, and e(t) is the error signal
Design of Fuzzy Controller

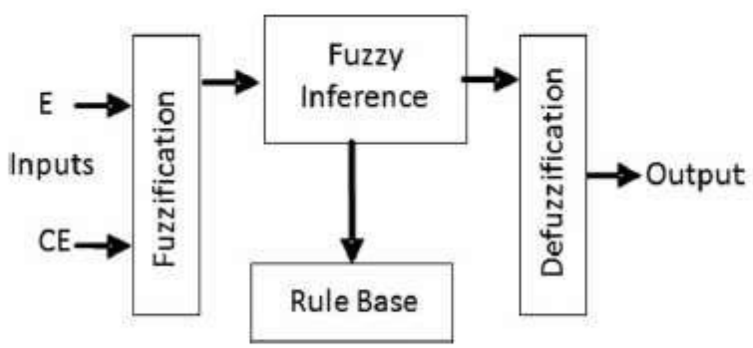


Fig.3 Block diagram of a fuzzy inference system.

It is possible to describe the research strategy and diffuse control study, shown in Figure 3・Obtain one or more extended assessments or other assessment of conditions in a system, which will be dissolved or checked. Treatment of input data according to fuzzy "assuming then" rules that can be transferred to the main page dialect words and combined with the usual non-diffuse formation. The means and weighting of the results of all the individual principles in the selection or choice of an output, in which is selected what to do or advise controlled system what to do. The output signal of the result - is an accurate de-fuzzified system. First, the different levels of performance (high speed, low speed, and so on) of the platform is determined by establishing membership functions of the fuzzy sets. Fuzzy inference system and calculation of back propagation. For a normal fuzzy inference, the parameters about participation opportunities are usually controlled by experience or experimental technique. The system of neuro-fuzzy adaptive induction can overcome this load across the road to detect how to adapt the information

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participant's information capabilities/output, taking into account the ultimate goal of representing such varieties in data values - automatically selects parameters relevant to the specific work registration. This strategy also works by studying neural systems.

Simulation of PID Controller

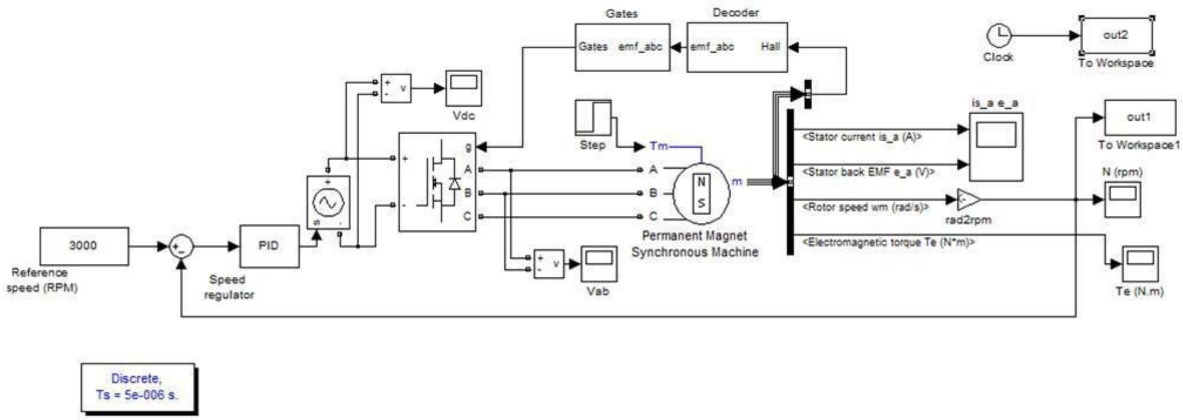

Figure 4.1: Simulation of PID Controller

As we are comparing the performance of PID, Fuzzy and ANFIS system above figure 4.1 shows the simulation of PID Controller. In this simulation model BLDC servomotor is placed which is connected with PID controller. Reference speed is provided with the gate signals of pwm technique. First if no controller is provided toBLDC motor drive and suddenly load is connected to the system then we will get the output with decrease in speed. In this simulation model PID controller is provided with servomotor drive system because of PID controller characteristics we will get the improved output of speed in BLDC servomotor drive as shown in result waveform.

Result of BLDC Drive by Using PID Controller

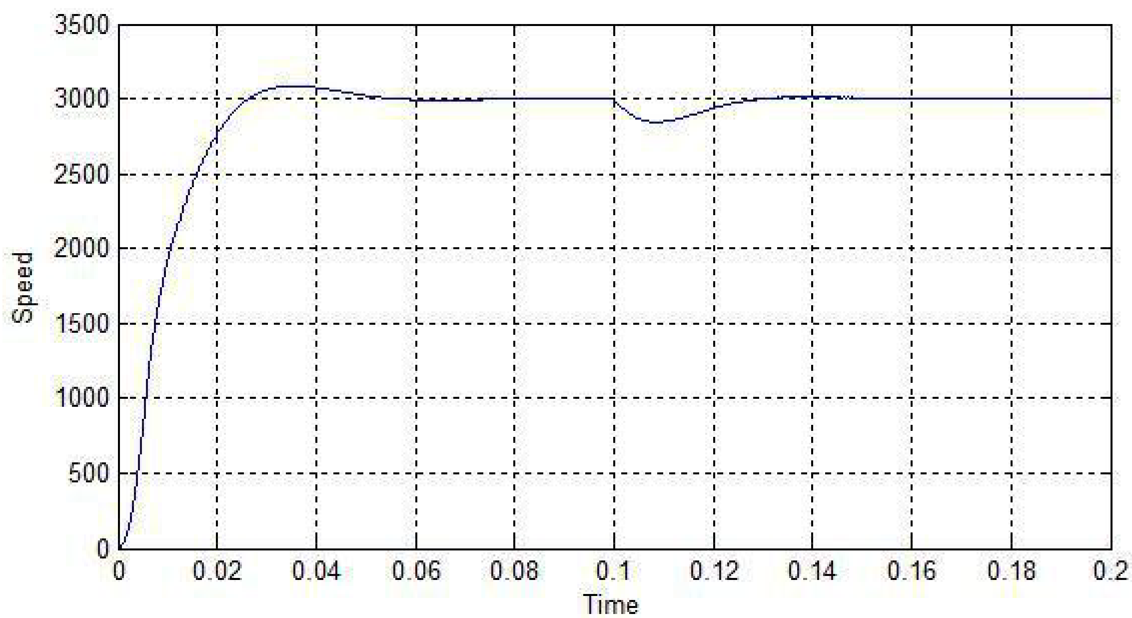

Figure 4.2: Output of BLDC drive by Using PID Controller

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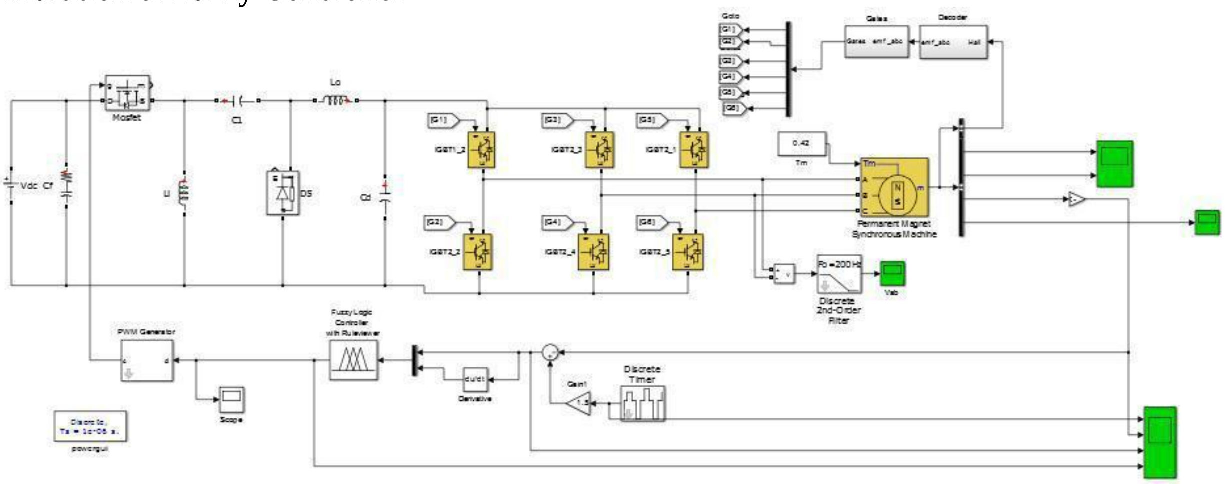
The experimental results obtained for BLDC servomotor drive under different operating conditions such as step change in reference speed, different inertia of the system, different phase resistance of the BLDC servomotor, and with load disturbance are done. Above figure 4.2 shows output of BLDC servomotor by connecting the PID controller. When load is connected to motor at that time speed of motor decreases, because of PID controller after some time period speed come to its original value.

Simulation of Fuzzy Controller



While we apply the Fuzzy controller on place of PID controller and load is connected to motor then settling time of motor is reduced. That is time required to come motor at its original state when Fuzzy controller is connected is less as compare to PID is less. Above figure 4.3 shows Simulation Of Fuzzy Controller, which consist of Fuzzy controller having six IGBT inverter system connected to BLDC servomotor drive with gate signal using hall sensor.

Results of BLDC By Using Fuzzy Controller

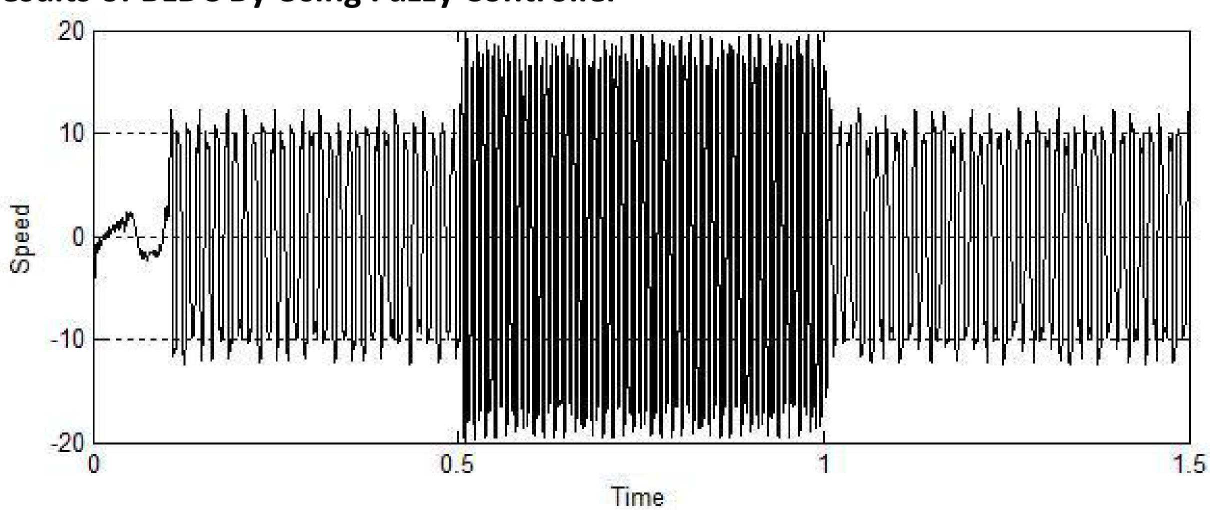


Figure 4.5: Stator Current of Fuzzy Controller

Below figure 4.5 shows stator current of BLDC motor drive when fuzzy controller is connected in place of PID.

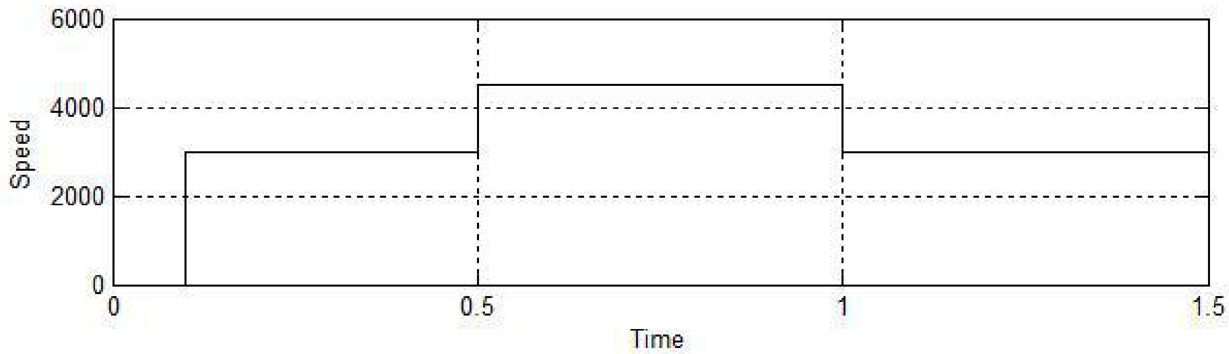


Figure 4.7: Reference Speed of Fuzzy Controller

Figure 4.7 shows the reference speed of BLDC motor drive when connected to fuzzy controller this output is with reference speed and time

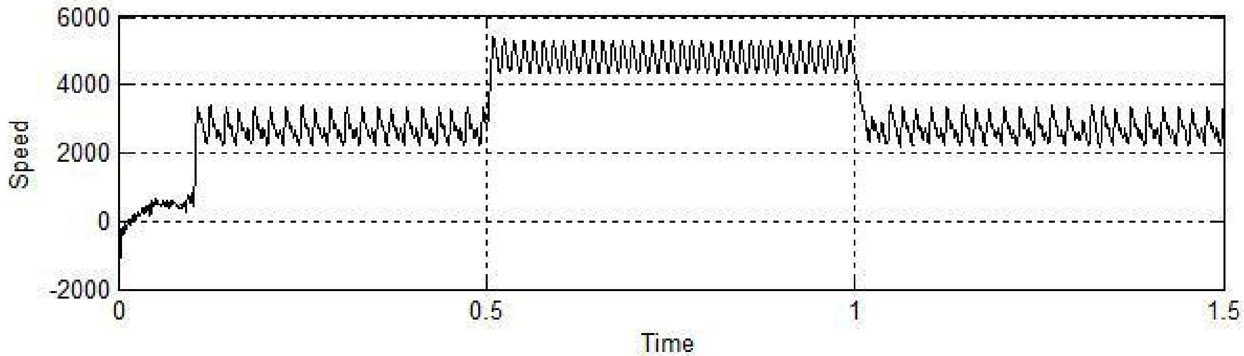


Figure 4.8: Actual Speed Output of Fuzzy Controller

By seeing the response of BLDC motor drive electromotive force, stator current and electromagnetic torque by connecting fuzzy controller, now below figure 4.8 shows the actual speed output with fuzzy controller

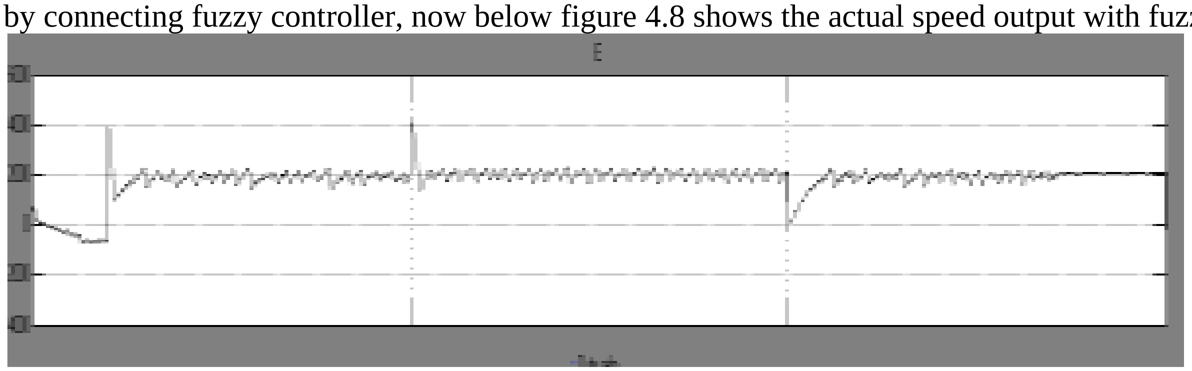


Figure 4.9: Error in Speed of Fuzzy Controller

Figure 4.9 shows output of error in speed of fuzzy controller. When sudden load is applied to motor speed of motor changes and this speed comes to its original position after some time this settling time is reduced by fuzzy controller.

Simulation of ANFIS Controller

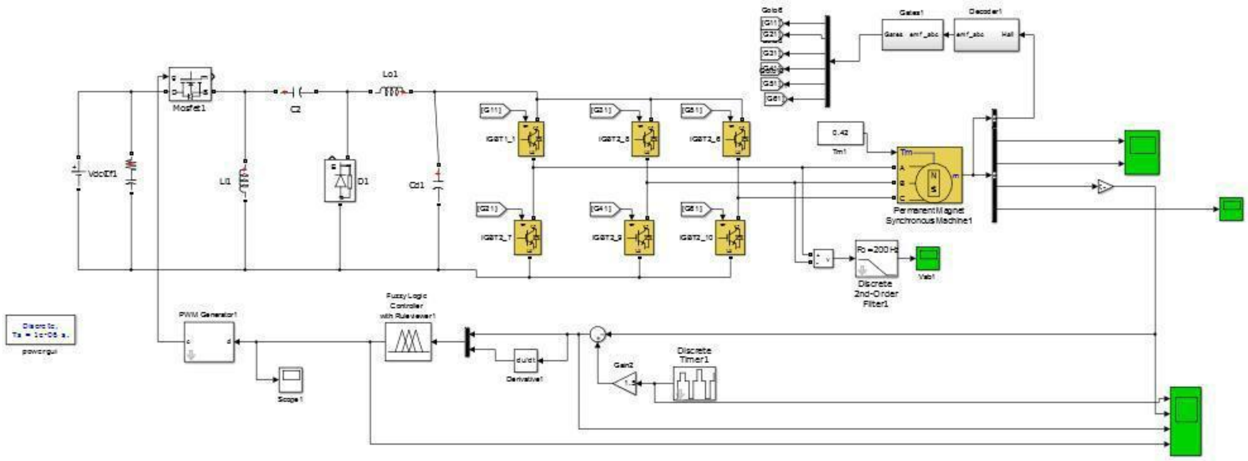


Figure 4.12: Simulation of ANFIS System

Results of BLDC Drive By Using ANFIS Controller

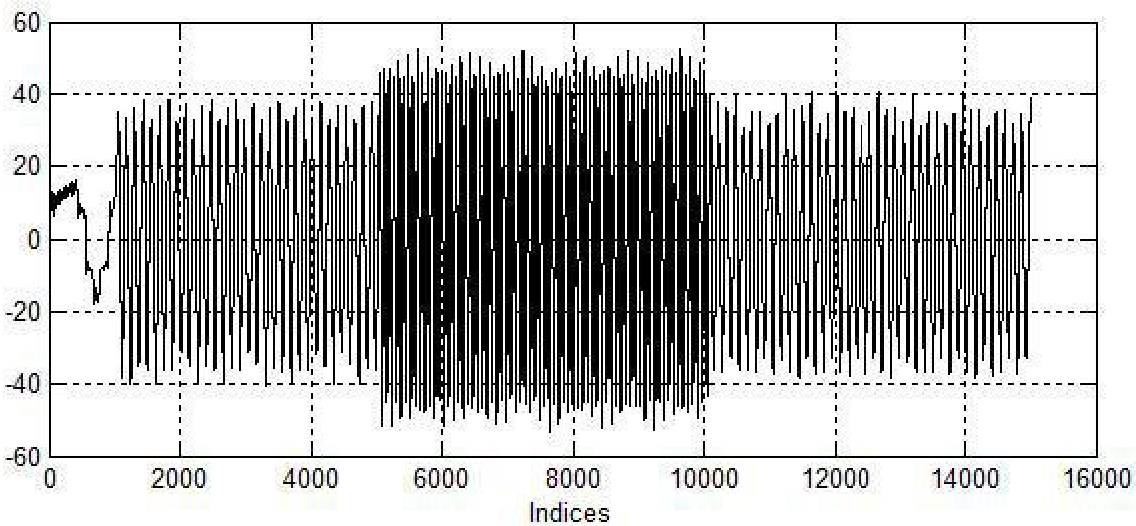


Figure 4.13: Electromotive Force of ANFIS Controller

Figure 4.13 shows electromotive force of system when connected to ANFIS system. Below figure 4.14 shows stator current of BLDC motor drive when ANFIS system is connected in place of fuzzy controller

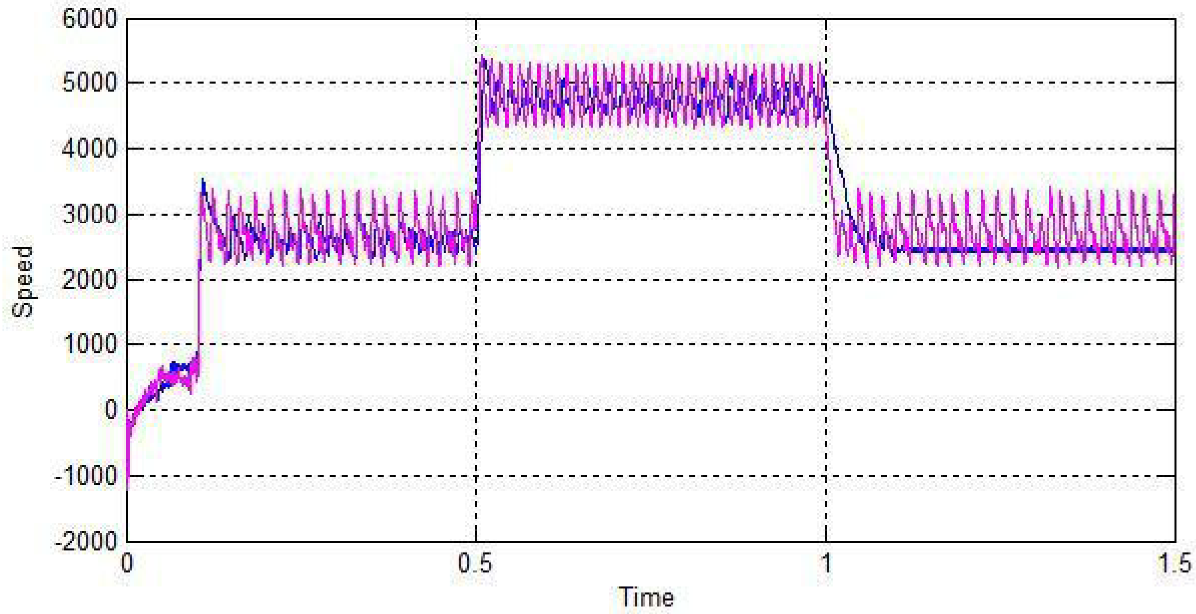


Fig. Output of BLDC drive by Using Fuzzy and ANFIS Controller

Finally in this thesis we have to compare the output of ANFIS controller with Fuzzy controller. The ANFIS controller gives more accuracy and effective out than Fuzzy and PID controller, below figure shows the comparison of Fuzzy controller and ANFIS controller by connecting to the BLDC motor drive in same window. From this comparison we can easily identify that ANFIS system is more effective than Fuzzy and PID controller. It can give the improved performance with different application connecting with BLDC servomotor drive

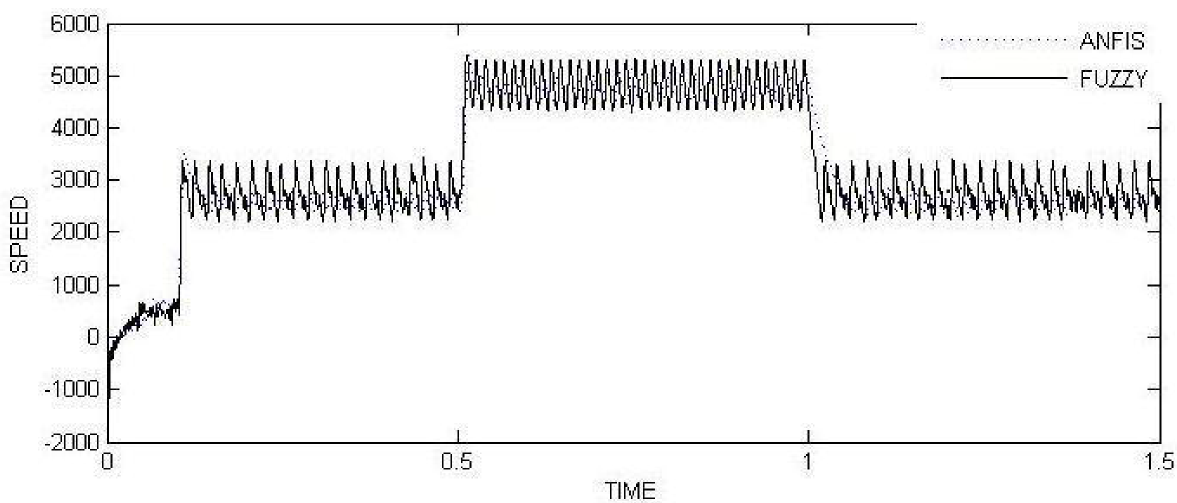


Figure 4.22: Comparison of Fuzzy And ANFIS System

CONCLUSION:

PID method and Fuzzy control Anfis has been successfully implemented for the servo motor drive system BLDC. The effect of changing parameters in the performance of the BLDC servo motor drive system has been studied with experimental results. However, the response speed of the BLDC servo drive based on the fuzzy controller is better than the response speed of the servo motor based on the BLDC PID controller and the response speed of the BLDC servo motor based on the ANFIS controller is better than the PID response speed and fuzzy controller, thus the BLDC PID controller Does not provide improved low variations in system performance parameters.

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