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Various Controllers for Performance Analysis and Implementation of Brushless DC Motor

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ABSTRACT:

The Brushless DC (BLDC) motors are becoming more popular due to its good electrical as well as mechanical characteristics. BLDC motors are widely used in industries because high efficiency, low cost, roughest construction, long operating life, noise less operation, no voltage drop across the brushes due to absent of brushes and commutator. These motors are now replacing the brushed DC motors & induction motors in variety of applications. A fuzzy controller offers better speed response for start-up. However, the main problem that arises with a conventional PID controller is that the parameters adjusted gain obtained from the drive control systems of the BLDC servo motor cannot produce a more transient response and a stable state under various operating conditions such as parameter variations, load disturbance, etc. This paper presents the design and simulation of the ANFIS controller for better performance of the servomotor of a brushless DC motor (BLDC). Capacity of BLDC servomotors based on ANFIS, fuzzy and PID controller are tested under different operating conditions, for example, changes in speed setting, parameter variations, load disturbance, etc. In this Paper, design and implementation of the ANFIS controller and its performance compared to the PID controller and fuzzy controller to show its capability to track the errors and utility of ANFIS controller in control applications. With the help of PID, Fuzzy, And ANFIS controller we can implement and analyse the overall performance of the Brushless DC motor.

KEYWORDS:

Brushless DC (BLDC) motor, PID controller,(FLC) Fuzzy logic controller, ANFIS controller (IGBT) Insulated Gate Bipolar Transistor.

I. 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[1].Industries use mainly two types of motors. (i) DC motors where the flux is produced by the current through the field coil of the stationary pole structure, (ii) permanent magnet brushless dc motors (PMBLDCM) where the permanent magnet provided the necessary air gap flux instead of wire wound field poles. back EMF [2]. 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. BLDCM is actually a permanent magnet synchronous motor (PMSM) with trapezoidal For controlling the speed of BLDC motor different controllers are used. most widely used controllers are conventional controller PI and PID. In practical control, there are various uncertainties in the plant. It may be because of payload variation, friction and many other external disturbances. The PI controller can be used for linear control application but as system becomes non-linear and complex PI controller not provided better control option, hence in that case conventional controller with intelligent controller is better option. The genetic algorithm based PID controller used for speed control for BLDCM, because due to its robust nature it's provided better control option [3].The BLDCM is an electronically commuted motor, having no brushes for commutation. The stator magnet which is usually made of steel sheet. The stator phase windings are inserted in slots or wound on the pole. The emf produced by the BLDCM is trapezoidal in shape which allows rectangular shape voltage to produce low ripples torque.

So in this respect BLDCM is behaving like the inverted DC commutator motor in which magnets rotate and conductors remain stationary[4]. In commutator DC motor, brushes are used to reverse the polarity of current but in case of BLDCM reversal is done using semiconductor switches.

In the vast majority of literary studies it was assumed that the parameters of the system will never show signs of changes in operating conditions, but in the parameters of the pragmatic application of mechanical stress, such as peace and friction can change due to inactivity or decoupling of the clutch components and load changes. The servo BLDC phase resistance may also vary slightly due to the variation of the terminal resistance of the wiring resistance and the semiconductor resistance due to temperature changes in the operating conditions. It was found that the ratio of the contactless battery at full load is 1:15, and the change in the instantaneous image delay is 10-20 times of the delay components for the decoupling or regular movement of automation control and the Positioning of basic weakness of the conventional controllers is that they can give a better transient and consistent state response when the parameters of the system for which they are planned are kept unchanged. In large part, the sensitive system of the parameters of the systems is changed during the operation. The realization of these controllers and their rationality for a wide range of servo motor drive BLDC studied under different operating conditions, such as changing the species of reference speed parameters and load influencing disturbing. The information regarding the various literary material for the purposes of this study as follows.

BLDC motor modeling, evaluation and control of network access evaluation [1] - [4]. The effect of the Change in Motor Parameters on the Performance of the BLDC Drive System is discussed in [6], [7] various fit Methods for the PID SE Controllers Description in [7]-[8]. The design, implementation and Performance Analysis of Fuzzy Logic Controllers (FLC) for divers applications such as the dc servo motor, BLDC motor, gas turbine, servo systems and so on are presented in [5] Design and implementation of adaptive controllers for the management and control of access to the network.

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II. MODELING OF BLDC SERVO MOTOR DRIVE SYSTEM:

The BLDC servomotor drive system consisting of BLDC servomotor and IGBT inverter is modeled [1]–[4], [15] based on the assumptions that all the stator phase windings have equal resistance per phase; constant self and mutual inductances; power semiconductor devices are ideal; iron losses are negligible; and the motor is unsaturated.

The equivalent circuit of the BLDC servomotor drive system is shown in Fig.1

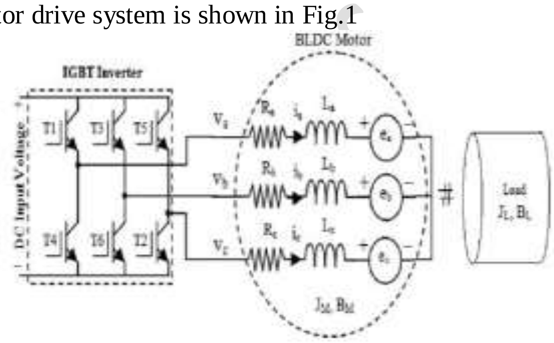

Fig. 1. Equivalent circuit of the BLDC servomotor drives system

The line to line voltage equations are expressed in matrix form as

$$\begin{bmatrix} V_{ab} \\ V_{bc} \\ V_{ca} \end{bmatrix} = \begin{bmatrix} R & -R & 0 \\ 0 & R & -R \\ -R & 0 & R \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + \begin{bmatrix} L-M & M-L & 0 \\ 0 & L-M & M-L \\ M-L & 0 & L-M \end{bmatrix} \times \frac{di}{dt} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + \begin{bmatrix} e_a - e_b \\ e_b - e_c \\ e_c - e_a \end{bmatrix}. \quad \ldots\ldots(1)$$

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

$$\begin{bmatrix} V_{ab} \\ V_{bc} \\ V_{ca} \end{bmatrix} = \begin{bmatrix} R & -R & 0 \\ 0 & R & -R \\ -R & 0 & R \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + \begin{bmatrix} L & -L & 0 \\ 0 & L & -L \\ -L & 0 & L \end{bmatrix} \times \frac{di}{dt} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + \begin{bmatrix} e_a - e_b \\ e_b - e_c \\ e_c - e_a \end{bmatrix} \quad (2)$$

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,

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respectively. The electromagnetic torque developed by the motor can be expressed as

$$Te = (ea\ ia + eb\ ib + ec\ ic)/\omega = KtI \ldots (3)$$

Where ia = ib = ic = Iω is the angular velocity in radians per second, and Kt is the torque constant.

Since this electromagnetic torque is utilized to overcome the opposing torques of inertia and load, it can also be written as

$$Te = T_L + J_M\, d\omega/dt + B_M\, w \ \ldots.(4)$$

Where T_L is the load torque, J_M is the inertia, and B_M is the friction constant of the BLDC servomotor.

The load torque can be expressed in terms of load inertia J_L and friction B_L components as

$$T_L=J_L*dw/dt+B_Lw \quad \ldots.(5)$$

The output power developed by the motor is

$$P = Te\omega \quad \ldots.(6)$$

$$E = ea = eb = ec = Kb\omega \quad \ldots.(7)$$

Where K_b is back EMF constant, E is back emf per phase, and ω is the angular velocity in radians per second.

The parameters that are likely to vary during the working conditions are R, JM, JL, BM and BL. These parameters can influence the speed response of the BLDC servomotor drive system. Increase in the value of energy storage inertia elements JM and JL will increase the settling time of the speed response or vice versa. The decrease in the values of power consuming friction components BM and BL will increase the deceleration time of the speed response or vice versa. Another parameter, which is likely to vary during working conditions is phase resistance of the BLDC servomotor due to addition of terminal resistance, change in resistance of phase winding, and change in on-state resistance of IGBT switches due to change in temperature. The change in phase resistance can also affect the speed response of the BLDC servomotor drive system. Mixed combination of inertia, friction, and phase resistance of the BLDC servomotor may lead to large overshoots that are undesirable in most of the control applications. Therefore, the BLDC servomotor drive system needs suitable controllers such as PID, Fuzzy or ANFIS controllers to speed up the response, reduce overshoot, and steady-state error not to meet up the applications requirements. In this paper, PID, Fuzzy and ANFIS controller-based BLDC servomotor drive is developed and their performance is investigated during different operating conditions such as step change in reference speed, different system parameters, and sudden load disturbance.

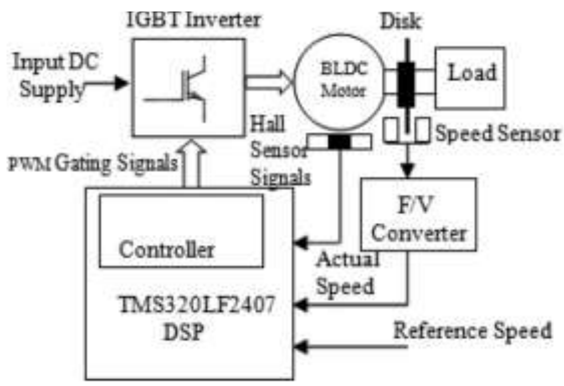

Fig. 2. Block diagram of the experimental setup.

A block diagram of the experimental setup is shown in Fig. The experimental system consists of four main components. This servo IGBT-power device BLDC inverter motor with load, speed, phase voltage and phase current and DSP measurement circuits. BLDC servo motor with electronic motor switching. Embedded three Hall sensors generate a signal depending on the position of the rotor. These signals are decoded to identify the position of the rotor and activate respective coil by switching the corresponding IGBT-converter switches. The Hall effect sensors used as inputs for the DSP through an IC buffer. Trigger signals generated by DSP for IGBT-switches also apply to the IC buffer. The PWM control method is used to control the voltage supplied to the winding to control the speed of the motor. The 20 kHz PWM signal is selected because there is no acoustic noise during engine operation. The duty cycle of the 20 kHz signal generated by the DSP changes to monitor the average current and the average voltage of the phase windings, and thus the torque generated by the motor. The operating cycle of the device is adjusted depending on the output signal. DC output The F signal of the V / V converter is set as one input to the DSP's A / D converter (ADC) to determine the actual motor speed. The speed reference is set using the potentiometer and the repeater voltage and is set as another ADC input signal to determine the reference speed. The function of the DSP processor is to calculate the error and change errors, store these values, calculate the sliding mode output of the controller, define a new cycle for the switching devices and perform electronic switching. PWM signals are generated to switch IGBT devices using components such as the EVA timer module, PWM channels, etc.

III. DESIGN AND IMPLEMENTATION OF PID CONTROLLER:

Proportional-integral-derived controllers are widely used in industrial control systems, as they require only a few parameters to adjust. PID controllers have the ability to eliminate constant error due to integral action and can anticipate changes in production due to derivative action when the system is exposed to a reference input signal. The most popular method is the calculation of the Ziegler-Nichols PID, which is based only on the parameters obtained from the response to the system stage. A block diagram of an experimental apparatus used to implement the controller is shown in Figure 2.The continuous control signal u(t) of the PID controller is given by

$$u(t)= Kp \ (e(t) \ +(1/Ti) \int e(t)dt \ +Td de(t)/dt) \quad \ldots(8)$$

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.

$$u(k)=u(k-1)+K1\times e(k)+K2\times e(k-1)+K3 \times e(k-2) \quad \ldots (9)$$

Where u(k − 1) is the previous control output, e(k − 1) is the previous error, and e(k − 2) is the error preceding e(k − 1). The constants K1, K2, and K3 are given by

$$K1 = Kp + TKi/2 + Kd/T \quad \ldots. (10)$$
$$K2 = -Kp - 2Kd/T + TKi/2 \quad \ldots. (11)$$
$$K3 = Kd/T \quad \ldots. (12)$$
$$Ki = Kp /Ti \quad \ldots. (13)$$
$$Kd = Kp\, Td \quad \ldots. (14)$$
$$T = 1/f \quad \ldots. (15)$$

Where f is the sampling frequency and T is the sampling rate.

IV. FUZZY LOGIC CONTROLLER:

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. For differentiation, the logic of the Boolean, the estimation of the reality of variables can be 0 or 1. The diffuse cause was stretched to cope with the idea of half-truth where the quality Reality can range from completely genuine and completely false. In addition, when using etymological variables, these varieties can be controlled with specific capabilities. Generally, under rational control, it is executed from four fuzzy components displayed in the fuzzification interface of the rice, the fuzzy principle of the induction motor and the network interface of the defuzzification.

Each of the parties together with the basic operations of fuzzy logic will be described in more detail below.

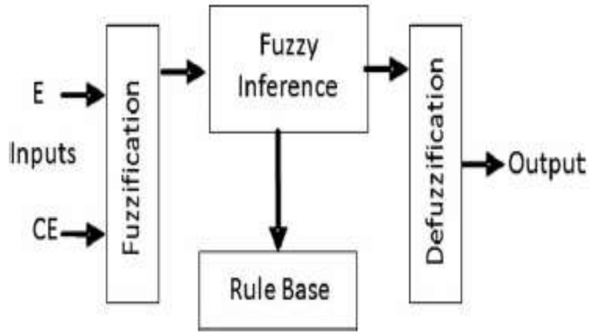

Fig.3 Block diagram of a fuzzy inference system.

- 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 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.

V. ADAPTIVE NEURO-FUZZY INFERENCE SYSTEMS (ANFIS):

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. Polynomials of zero and first order are used as the constant and near linear models of

Sugeno, respectively. In addition, in the process of defuzzification, Sugeno diffuse model is a simple calculation of the weighted average. Fuzzy space is divided by partition grid according to the preceding number MF, and each diffuse area covered by the rule. On the other hand, each fixed and adaptive network node performs a single function or a sub-Sugeno model, so that the overall performance of the network is functionally the same as that of the diffuse model. The network uses an adaptive optimization algorithm to change the parameters of the fuzzy inference system. The adaptation process is aimed at obtaining a set of parameters for which it minimizes the error between the actual output of the diffuse model and the established target of training data. You can use classic optimization techniques such as backward propagation as well as hybrid algorithms. The total number of modifiable ANFIS parameters is the important computational effort required to complete the tuning process. ANFIS combines the advantages of fuzzy systems and adaptive networks into a hybrid intellectual paradigm. Systems of flexibility and subjectivity with fuzzy inference when added to the optimization of the power of adaptive networks provide a remarkable resistance Amphism simulation, training, nonlinear assignment and pattern recognition.

VI. RESULTS AND CONCLUSION:

A. RESULTS:

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 and below figure show the results with PID, Fuzzy and ANFIS controller. Below figure 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 it's original value.

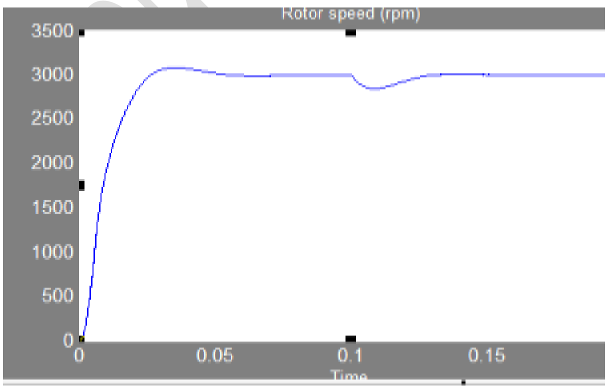

Fig. 4 Output of BLDC drive by Using PID Controller

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.

Below figure shows all outputs of Fuzzy controller.

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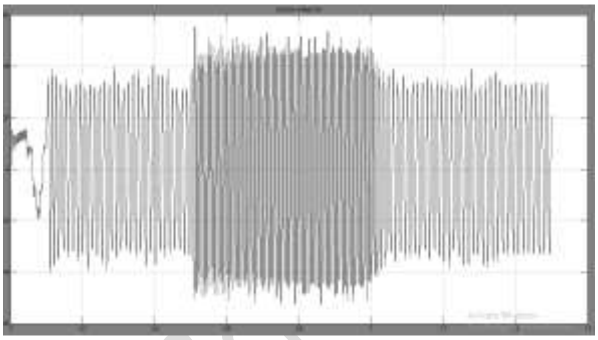

Fig. 5. Line to line voltage of fuzzy controller

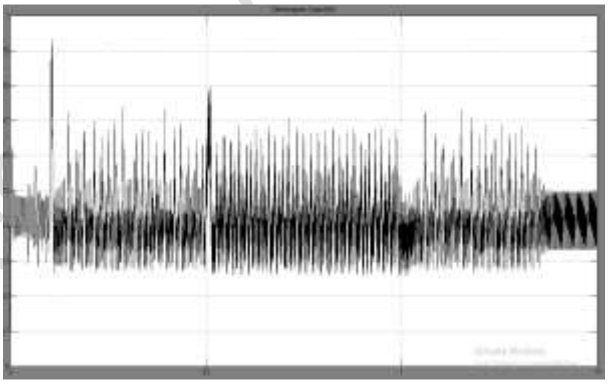

Fig. 6.Electromagnetic torque fuzzy controller

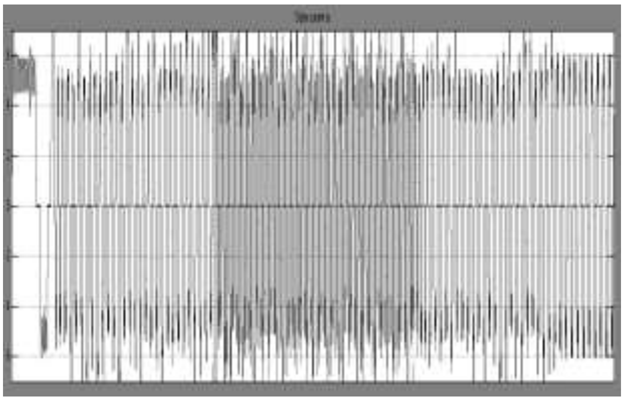

Fig. 7.Stator current of fuzzy controller

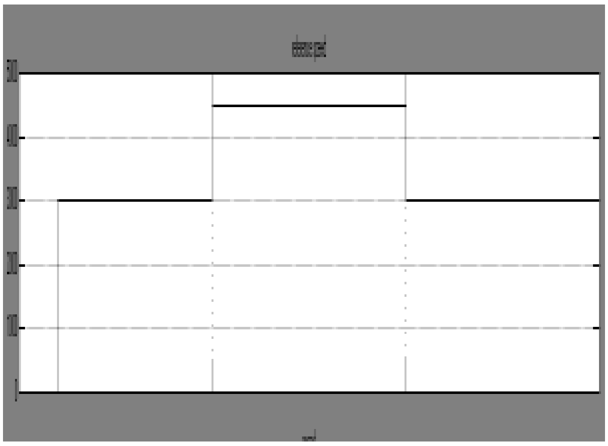

Fig. 8.Reference speed of fuzzy and ANFIS controller

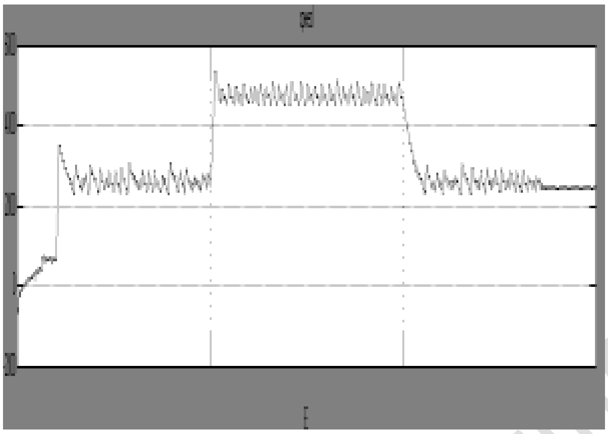

Fig. 9. Actual speed of fuzzy controller

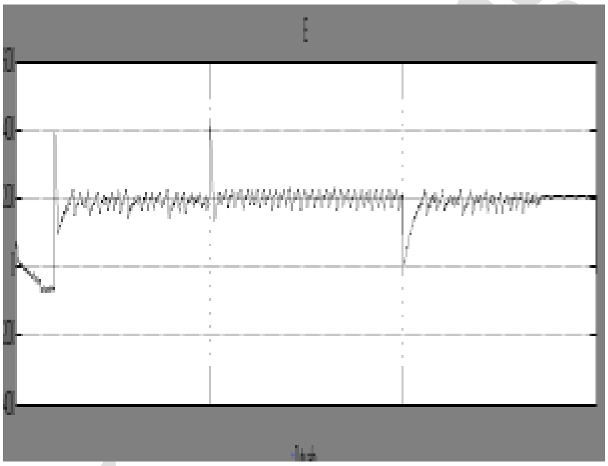

Fig. 10.Error in speed of Fuzzy Controller

Above figure 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 it's original position after some time this settling time is reduced by fuzzy controller

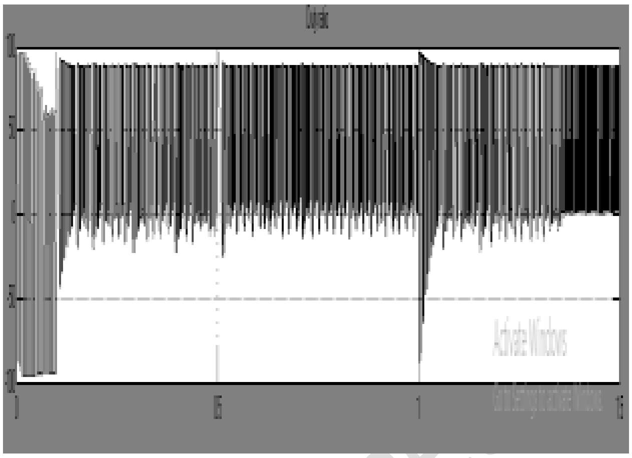

Fig. 11. Duty Ratio of fuzzy controller

After seeing all parameters of fuzzy controller now below figures shows all the parameters such as electromotive force, stator current, electroagnetic torque, reference speed, actual speed output, error in speed, duty ratio and line to line voltage of ANFIS controller.

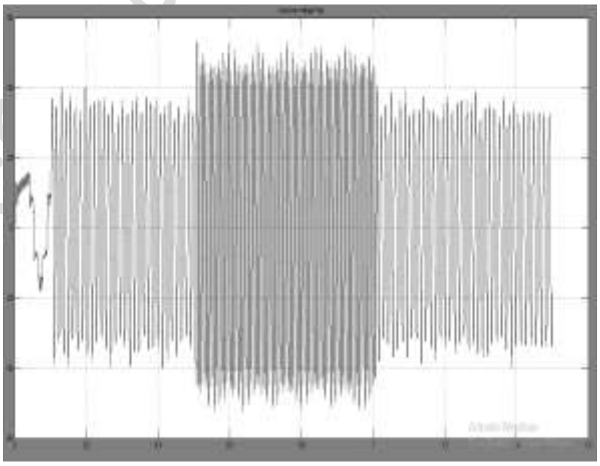

Fig. 12. Line to line voltage of ANFIS controller

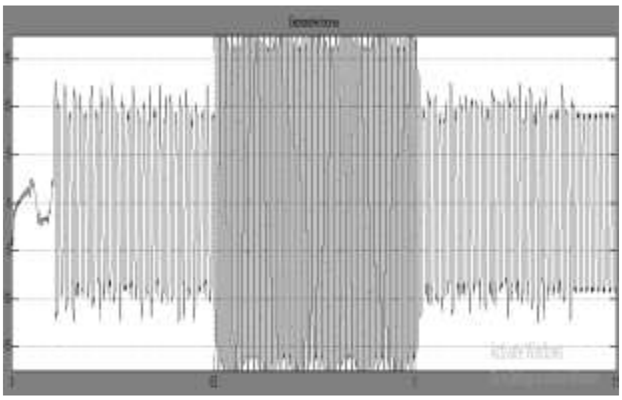

Fig. 13.Electromotive force of ANFIS controller

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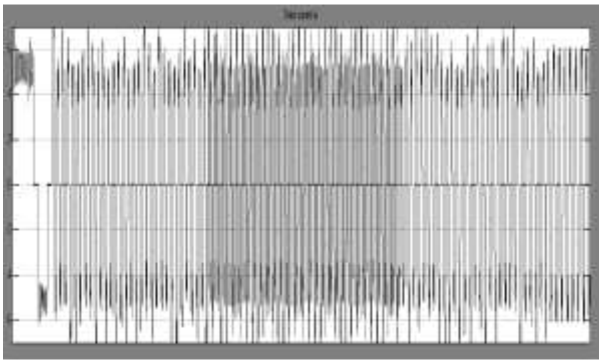
Fig. 14.Stator current of ANFIS controller

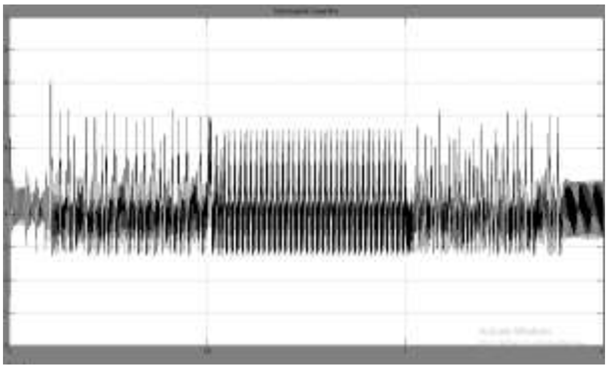
Fig. 15.Electromagnetic torque ANFIS controller

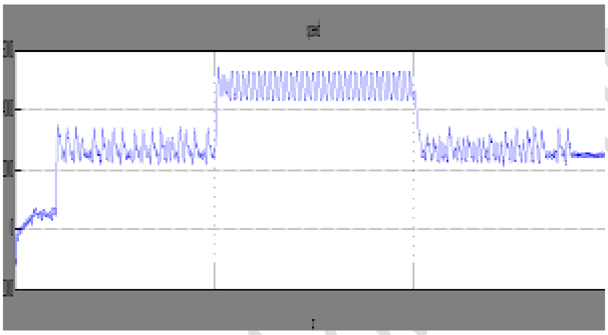
Fig. 16.Actual speed output of ANFIS controller

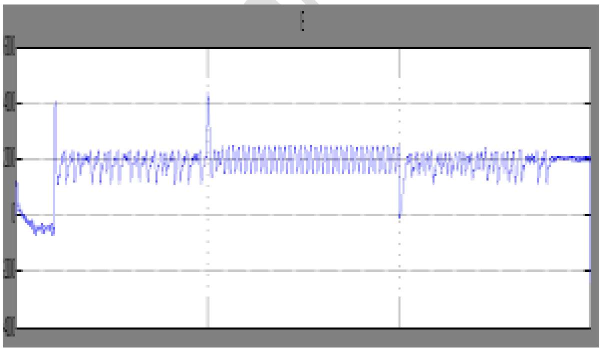
Fig. 17.Error in speed of ANFIS Controller

Above figure 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 it's original position after some time this settling time is reduced by ANFIS controller.

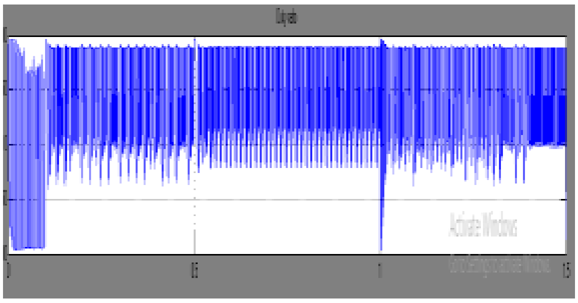
Fig. 18. Duty Ratio of ANFIS controller

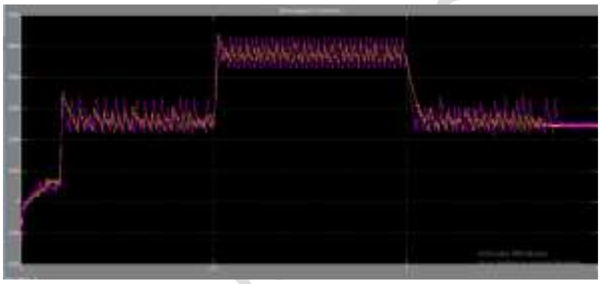
Fig.19. Output of BLDC drive by Using Fuzzy and ANFIS controller.

B. 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 BKEPT 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. However, the experimental results clearly show that the BLDC servo motor based on the fuzzy controller and ANFIS can provide an improved reaction rate in sequence with the same rise time and there will be a stabilization time when the system is under the load of perturbations, the variation of the parameter and the pitch of the change in the initial speed. Since the ANFIS control system is easy to design and implement effective to cope with uncertainty and parameter changes and has better overall performance, the BLDC servo motor drive system based on the ANFIS controller on the PDC-based BLDC servo motor and the fuzzy controller may be preferred. Automation, robotics control systems and the position of speed and industrial control of applications.

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