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Comparison of Fuzzy Logic & Hybrid Controller based DTC Technique of Induction Motor

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ABSTRACT: In this paper, a comparison is done of direct torque control technique using fuzzy logic controller (1) & an adaptive neuro fuzzy interference (2) based hybrid system for controlling speed of an induction motor (4) is presented. The proposed hybrid system of speed control results in high performance of induction motor having potential features of both ANN and FLC. The DTC method using FLC and ANFIS is compared to know the better one among them. The proposed schemes of DTC of induction motor is implemented in MATLAB and simulation results are presented to get better view of their comparison, letting us to know that the induction motor performs better under which scheme FLC or ANFIS.

KEYWORDS: Adaptive Neuro Fuzzy Interference System (ANFIS),Direct Torque Control (DTC),Fuzzy Logic Controller (FLC),Induction Motor (IM)

I.INTRODUCTION

Induction motors plays vital role in the industrial world when compared to other AC motors, because of its construction being simple and robust compared to others. Speed control of an induction motor is an important task, but controlling induction motor is complex due to its non linear nature and parameters gets changed with change in operating conditions. Hence an advance method is required; DTC is applied here for that purpose for controlling speed of an induction motor. In recent years the DTC method has gained a lot of attention due to its nature of controlling the speed of IM directly by controlling torque of the machine.DTC method is one of the methods which are used in variable frequency drives to control the torque (later speed) of a three phase induction motor. Fuzzy logic controller is used to overcome the high torque ripples being generated under DTC technique of speed control. Later, an adaptive neuro fuzzy interference system is used along with DTC technique to control speed of induction motor. Afterwards these two schemes of speed control are compared to get a clear view of better scheme among them.

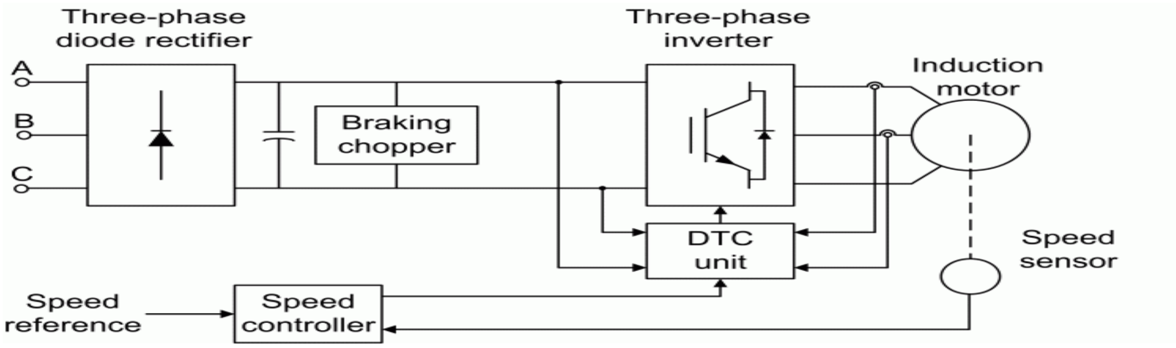

Figure 1: Block Diagram of Direct Torque Control of Induction Motor

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II.DIRECT TORQUE CONTROL OF INDUCTION MOTOR AND MATHEMATICAL EQUATIONS

The main objective of using DTC method for speed control of an induction motor is to choose the flawless vector of the voltage which rotates the flux and produces the direct torque. In conventional DTC method speed control of IM involves direct control of stator flux vector by applying optimum voltage switching vectors of the inverter. For this controlling process, stator current should be decoupled into two independent components of flux and torque components. For this decoupled process in the DTC method we have used Clarke transformation method. The DTC method gives very fast torque responses and flexible control of the induction motor.

i) VOLTAGE EQUATIONS:

$V_{s\alpha}=\Upsilon_s i_{s\alpha}+P\Psi_{s\alpha}$

$V_{s\beta}=\Upsilon_s i_{s\beta}+P\Psi_{s\beta}$

$V_{r\alpha}=\Upsilon_r i_{r\alpha}+P\Psi_{r\alpha}+\Psi r\omega_r$

$V_{r\beta}=\Upsilon_r i_{r\beta}+P\Psi_{r\beta}-\Psi_{r\alpha}\omega_r$

Here $V_{s\alpha,}$ $V_{s\beta,}$ $V_{r\alpha}$ and $V_{r\beta}$ are α axis and β axis voltages of stator and rotor respectively; $i_{s\alpha}$ and $i_{r\beta}$ are the axis and β axis currents of stator and rotor respectively.

ii) STATOR FLUX EQUATIONS:

$\Psi_{s\alpha}=\int (V_{s\alpha}-\Upsilon_s i_{s\alpha})\, dt$

$\Psi_{s\beta}=\int (V_{s\beta-}\Upsilon_s i_{s\beta})\, dt$

iii) ELECTROMAGNETIC TORQUE EQUATIONS:

$Te=3/2.\ P/2(\Psi_{s\alpha} i_{s\beta}-\Psi_s\beta i_{s\alpha})$

$T=T_e-T_L=P/2(J.d\omega r/dt+B\omega_r)$

iv) VECTOR DIAGRAM:

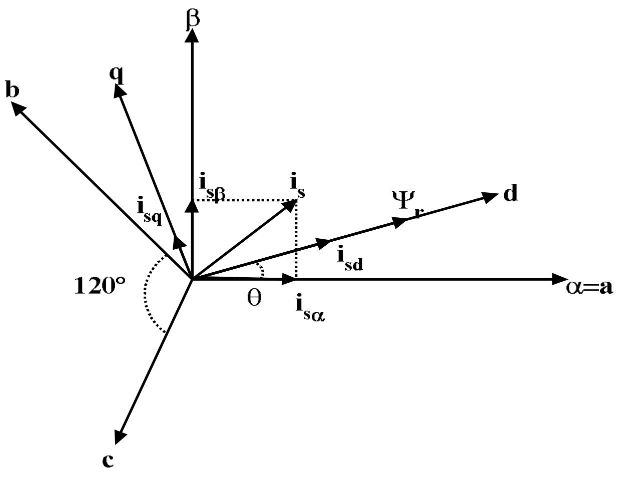

Figure 2: Vector Diagram of DTC of Induction Motor

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The vector diagram of flux linkages in the stator and rotor winding has been illustrated in figure (2). The three phase current i_a i_b i_c are converted into a two phase orthogonal system with axes a and b by Clark's Transformation technique. Here a component is assumed as it is equal to the axis a as best suited for our convenience as shown in figure (2). Obtained orthogonal currents i_a and i_b are once again transformed into a time invariant, rotating orthogonal system corresponds to the field and torque components d and q of the equivalent rotor currents i_d and i_q. Then α/β coordinate frame is rotated anti clockwise to line up with the rotor flux axis Ψr. Later the angle of rotation (θ) is determined with help of the motor model.

III. FUZZY LOGIC CONTROLLER

The direct torque method of speed control of induction motor is quite advantageous in respect to other methods of speed control. In this method high torque ripples gets generated. FLC is used to eliminate these ripples making DTC method more effective and reliable

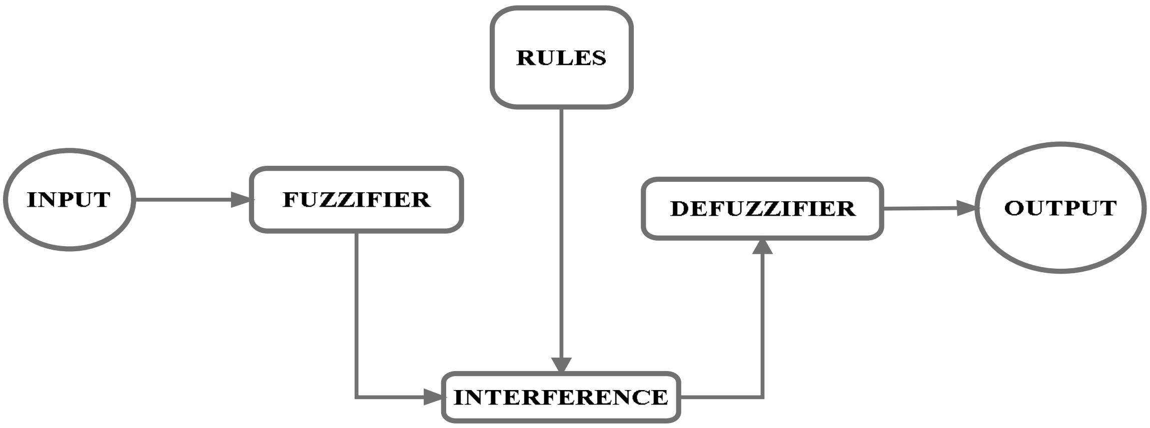

Figure 3: Block diagram of FLC

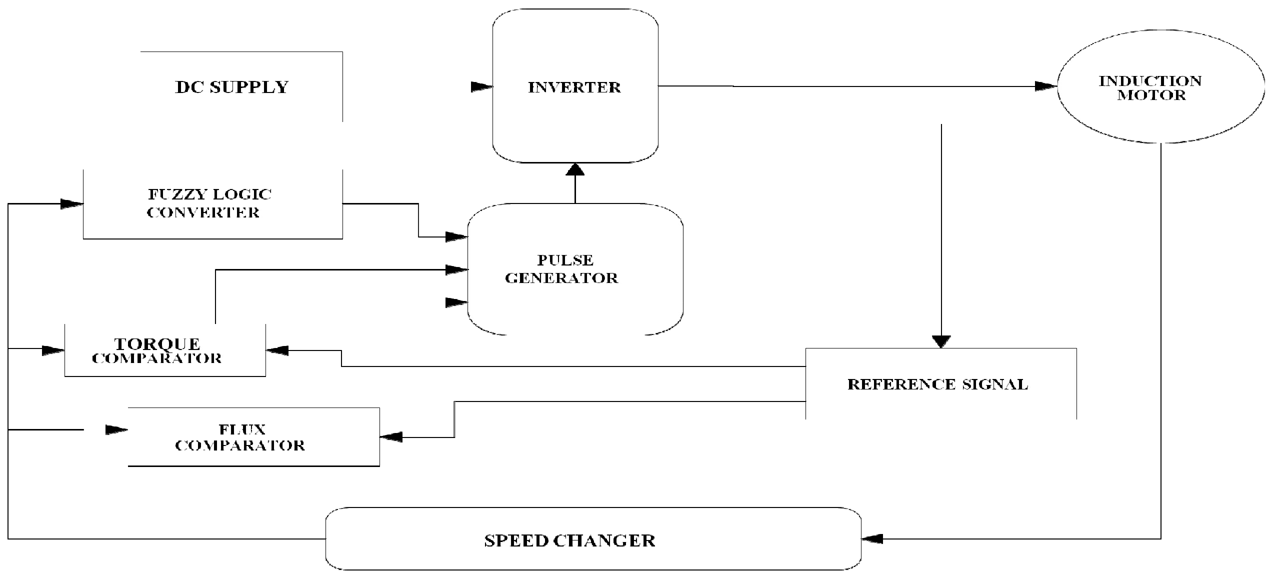

Figure 4: Block diagram of DTC with FLC

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IV.ADAPTIVE NEURO FUZZY INTERFERENCE SYSTEM

Combining features of fuzzy logic and artificial neural network results in ANFIS system. It allows us to hold all the advantages of both the system i.e. fuzzy logic and neural network. The ANFIS is combination of NN and FLC used for speed control of IM. The fuzzy logic controller and neurons of NN are implemented based on field forward technique. In the hybrid system the data set are evolved by neural network in terms of actual torque and change in torque and reference torque of the motor. The generated data set is provided to fuzzy interference system where fuzzy control rules are generated. This adaptive system is generated in two phases, training and testing.

A) Training Phase:

The first phase of the two is training phase; it is used to generate training data set. In the mentioned control approach, the actual and change in torque of motor values are generated in form of vector and data is provided to neural network. Then the data is trained by back propagation training algorithm with respect to the actual torque of motor. Then the trained data is applied to the fuzzy interference system for generating the control fuzzy rules. In ANFIS, the fuzzy rules base control interference system is automatically generated.

B) Testing Phase:

After training phase comes testing phase of ANFIS, it is used for creating the test speed control system model. In the testing phase, the actual torque and change in torque of motor is applied as an input, the appropriate control electromagnetic torque is obtained from the interference system.

C) Features of ANFIS:

In the proposed system of speed control, the ANFIS is been used for the set of features which are based on neural network and fuzzy system. The features of neural network are the structure network of feed forward type and the network training algorithm is back propagation type. In back propagation training algorithm, the data is trained based on the network error. The error of the network is the difference between the target value and the actual value. The error of the network is difference between the target value and the actual value. Hence an appropriate control model can be developed. The model proposed in fuzzy interference system is based on the Sugeno model which m contains a set of rules. The fuzzy concept includes three steps which are fuzzification, rule base decision making and fuzzification.

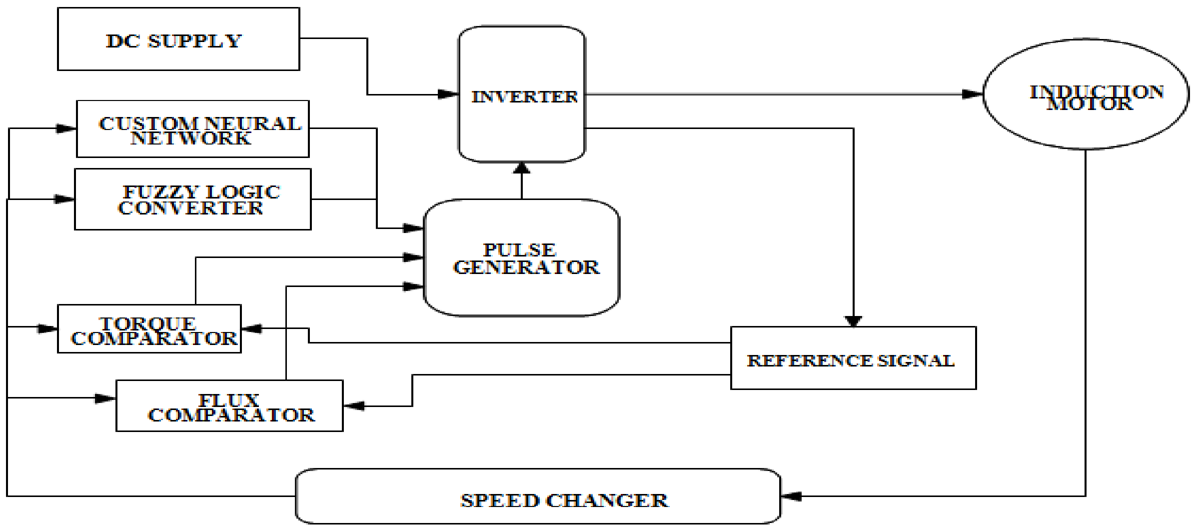

Figure 5: Block Diagram of DTC with ANFIS

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V.SIMULINK MODEL

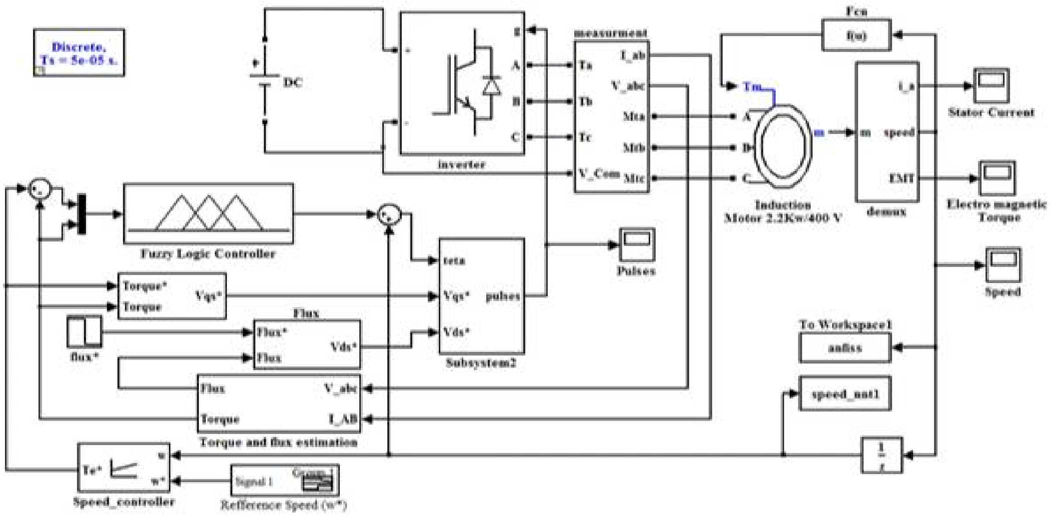

Figure 6- Simulink model of DTC with FLC

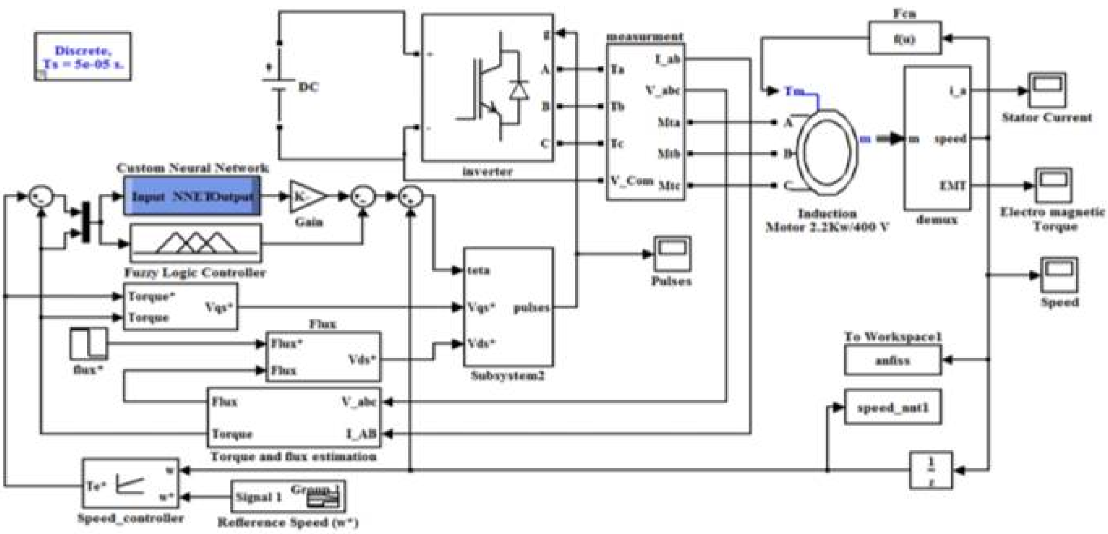

Figure 7: Simulink model of DTC with ANFIS

VI. RESULT AND DISCUSSION

The dynamic response of an induction motor can be described by choosing the speed set point as 80rad/sec from rest point at duration of 0.5sec. Later this speed set point is varied from 80rad/sec to 60rad/sec .Afterwards this speed set point is varied from 60ra/sec to 100rad/sec at duration of 1 sec.

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The various performance results of current, voltage flux, torque, speed of the motor with fuzzy logic controller has been represented here in graphical form.

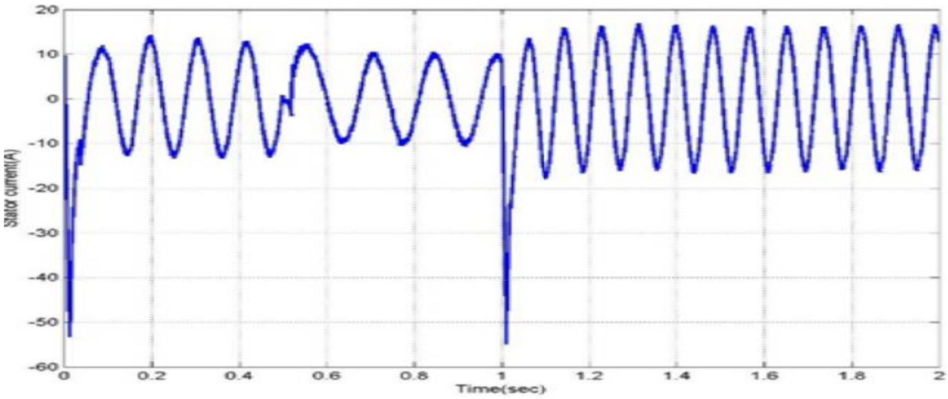

Figure 8: Dynamics of Stator Current

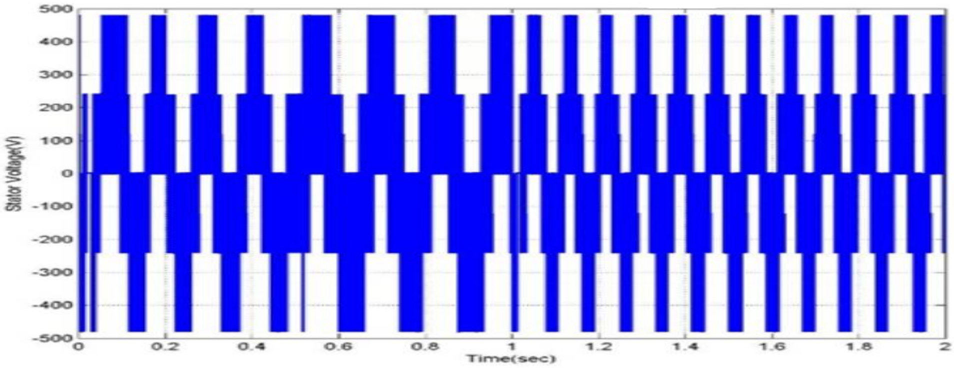

Figure 9: Transformed d-q axis of Stator Voltage

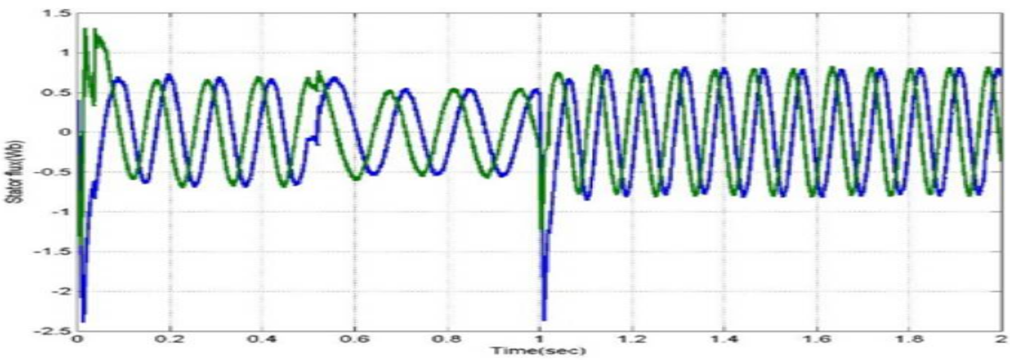

Figure 10: Dynamics of d-q axis Stator Flux

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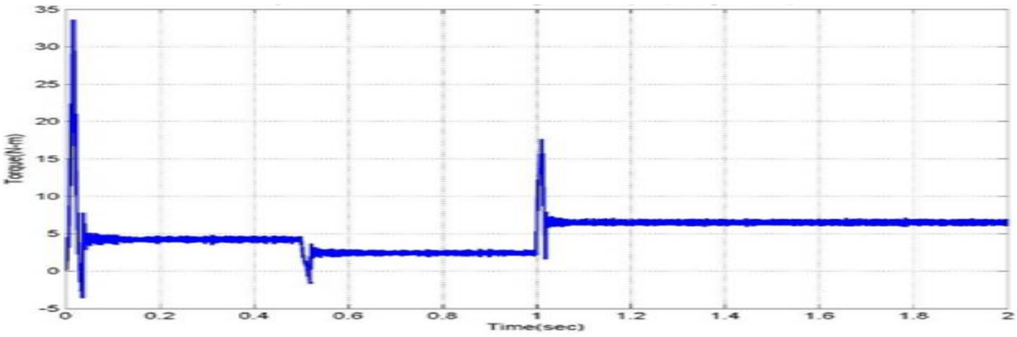

Figure 11: Variation of Electromagnetic Torque

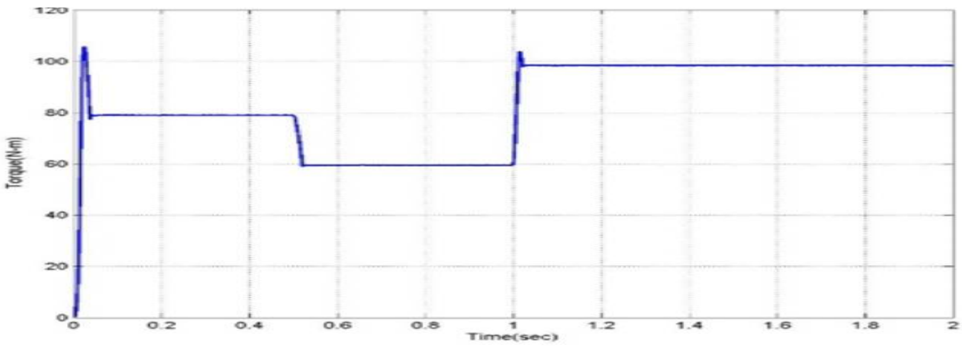

Figure 12: Performance of Speed

The various performance results of induction motor under ANFIS system are shown below:

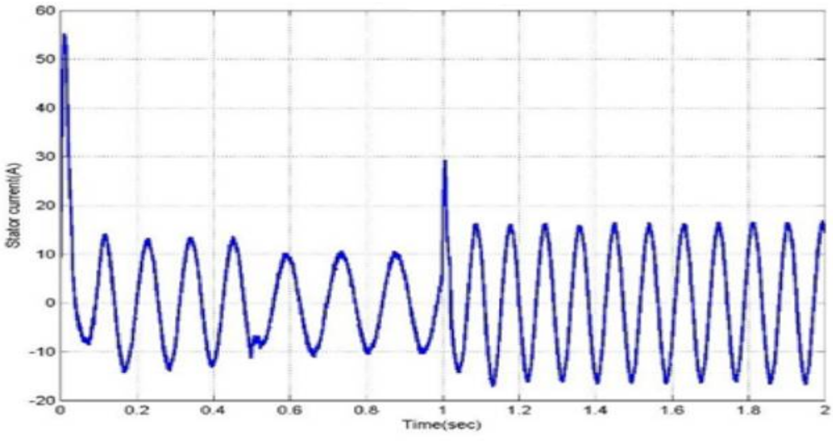

Figure 13: Dynamics of Stator Current

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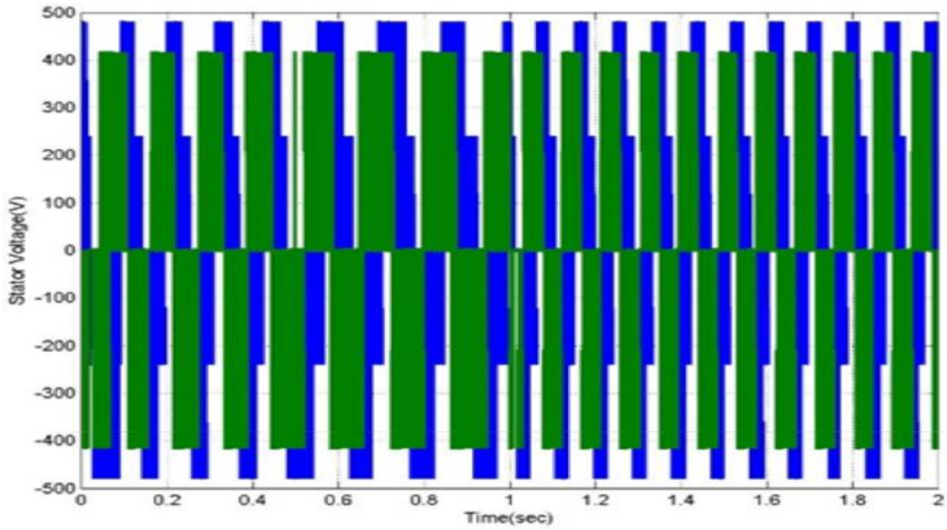

Figure 14: Transformed d-q axis of Stator Voltage

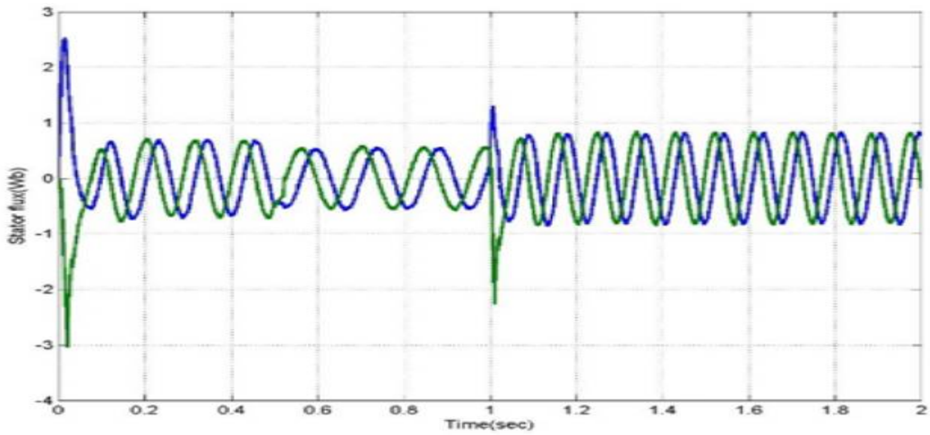

Figure 15: Dynamics of d-q axis Stator Flux

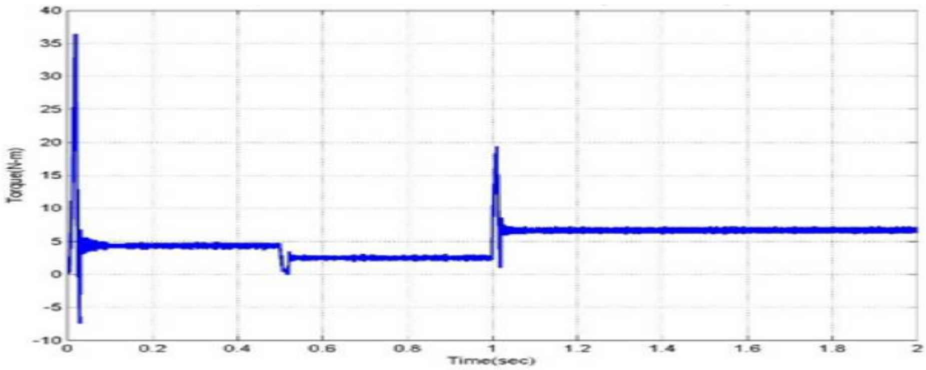

Figure 16: Variations of Electromagnetic Torque

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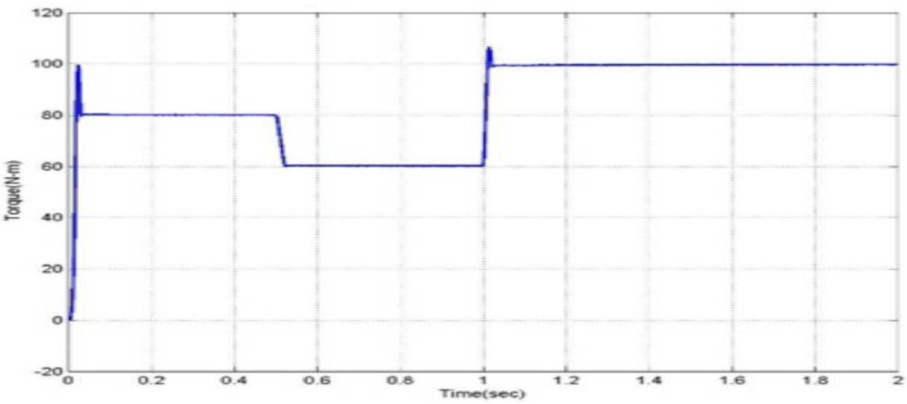

Figure 17: Performance of Speed

The speed of motor with fuzzy logic controller and proposed ANFIS controller are compared in following figure below.

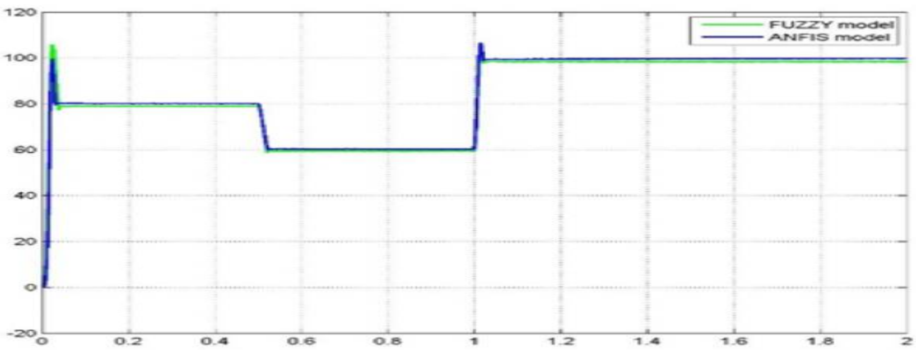

Figure 18: Comparison of Performance of Rotor Speed

From the above comparative study, we found that the proposed ANFIS speed controller provides smooth speed control performance with less amount of settling time, peak overshoot and steady state error when compared to the fuzzy logic controller. The fuzzy controller offers high overshoot, oscillations. Hence by above graphical results we came to know that proposed ANFIS speed controller is better than fuzzy logic controller.

VII. CONCLUSION

The proposed DTC schemes of speed control of an induction motor with fuzzy logic control and adaptive neuro fuzzy interference system were implemented in MATLAB/Simulink platform. The performance of the induction motor was tested under FLC and ANFIS schemes and were compared with each other. From this comparative analysis of both FLC and ANFIS schemes the ANFIS scheme of speed control was found to be better a technique in comparison to fuzyy logic control scheme

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Appendix-A

Parameters	Values
Nominal power	2200 watts
Line to line voltage	400 volts
Frequency	50 Hz
Stator resistance	3.67 ohm
Stator inductance	0.0269 H
Rotor resistance	2.1 ohm
Rotor inductance	0.0269 H
Mutual inductance	0.0324 H
Inertia	0.0155 kg.m^2
Friction	0.0025 N.m.s
Number of poles	2

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BIOGRAPHY

Ubaidullah Received B.Tech. degree from Sagar Institutue of Technology and Management, Barabanki, Uttar Pradesh (Dr. A.P.J. Abdul Kalam Technical University, formerly known as UPTU) in Electrical Engineering in 2014 and pursuing M.Tech. degree in Power System and Control from Babu Banarasi Das University(BBDU), Lucknow, Uttar Pradesh. Area of research is induction motor and control.

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