Comparison Analysis of DTC Fed Induction Motor Drive with or without using Fuzzy Logic Controller

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***Abstract*— This paper presents a direct torque control (DTC) of three phase induction motor drive (IMD) using P and fuzzy logic controller (FLC) for comparison of torque stator current and flux trajectory and show how much ripples is minimization while using fuzzy logic controller .In This control technique the error signal from torque, flux and stator angle is used for selecting the stator voltage vector.DTC use hysteresis band controller for selection of vector .The main drawback with the conventional DTC of IMD is torque ripples. This drawback was eliminating by using with the proposed control technique. In this method the p controller is used for regulation the speed error in speed loop while the FLC is reducing the torque ripples. The DTC is calculated by reference of stator flux hysteresis band which is the compression of instantaneous value and reference stator fluxes and the reference of torque hysteresis band will generates from FLC. The amplitude of the reference stator flux is kept constant at rated value. The proposed DTC technique gives better performance in the three-phase IMD than conventional DTC technique. The simulation results of both conventional and proposed control technique is presented, using MATLAB/SIMULINK.**

Keywords*— Direct Torque Control (DTC), Fuzzy Logic Control (FLC), Induction Motor Drives (IMD), P controller, Space Vector Modulation (SVM).

I. INTRODUCTION

Before the evolution of AC drive the industries use separately excited dc motor but the problem with these type of motor and its drive is commutator which make the size and hence the cost of drive is high. Due to this drawback the AC drives are become more and more popular, especially induction motor Drives (IMD), because of robustness, high efficiency, high performance rugged in structure and ease of maintenance so (IMD) is now widely used in industrial application. The IMD control methods are divided into two methods such, scalar and vector control. The scalar control is operating in steady state and controls the magnitude of speed , current, voltage, and flux linkage in the space vectors; and it does not provide the decoupled control as in dc motor which make cause the automatic change in one value when other value change which is undesirable . Thus, the scalar control does not operating in the space vector position during transient state. The vector control, which is based on relations valid for dynamic states, not only control the magnitude it also deals with the position of current, voltage, and flux linkage of space vector are controlled. T he vector control, is subdivide into two type one is field oriented control (FOC) is presented by F.Blaschke (Direct FOC) and Hasse (Indirect FOC) in early 1970's, and FOC gives high performance, and high efficiency for industrial applications [1].

The FOC is good in high dynamic performance, low stator flux and torque ripples, switching frequency, and maximum fundamental component of stator current, but FOC method has some drawbacks, While using the FOC technique there is lots of mathematical equation because In this FOC, the motor equations are transformed into a coordinate system that rotates in synchronism with the rotor flux vector control [2]. Such as requirement of two co-ordinate transformations, current controllers, and high machine parameter sensitivity. This drawback was eliminated using the new strategies for torque and flux ripple control of IMD using DTC was proposed by Isao Takahashi and Toshihiko Noguchi, in the mid 1980's [3]. Comparing with FOC, DTC has a simple control scheme and also very less computational requirements, such as current controller, and co-ordinate transformations are absent in DTC. The main feature of DTC is simple structure and good dynamic behavior and high performance and efficiency [4, 5, 6]. The new control strategies proposed to replace motor linearization and decoupling via coordinate transformation, by torque and flux hysteresis controllers [7]. This method referred as conventional DTC [8].

In the conventional DTC has some drawbacks, such as, variable switching frequency, high torque and flux ripples, problem during starting and low speed operating conditions, and flux and current distortion caused by stator flux vector changing with the sector position [8], and the speed of IMD is changing under transient and dynamic state operating condition. In order to overcome with this problem, the proposed DTC with P and FLC is using. The P controller is using for speed control in the SR loop and the FLC is using for stator flux and torque ripple reduction in the torque control loop [9]. The conventional and proposed DTC of IMD simulation results are presented and compared. Finally the effectiveness, validity, and performance of DTC of IMD using both conventional and proposed controllers are analyzed, studied, and confirmed by simulation results using MATLAB/SIMULINK.

II CONVENTIONAL DTC DRIVE

The Direct Torque Control method of induction motor drive contains two hysteresis controllers (Flux hysteresis and Torque Hysteresis, estimator for estimating the value of flux and torque and a voltage source inverter. Flux and torque estimator are used to calculate the actual value of drive which

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then compared with the reference value of torque and flux The error is then fed to both the hysteresis by which appropriate value of stator voltage is selected from VSI switching fed to induction motor.

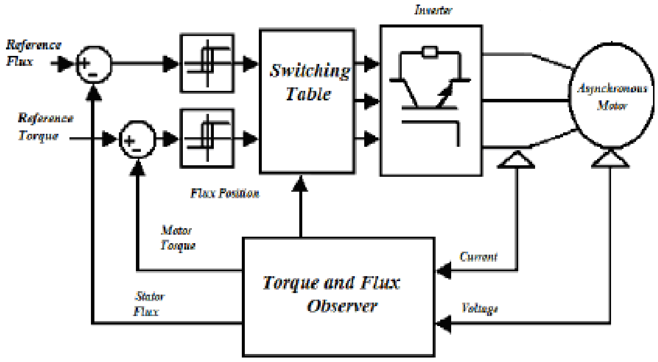

Fig 1: conventional DTC

A: Voltage source Inverter (VSI)

The VSI contain of eight voltage space vector from which six are active voltage vector (V_1- V_6) and two zero voltage vectors (V_0,V_7). There are 3 Switches S_a , S_b ,S_c whose upper part is on when the value is 1 and lower part is on when value is 0 .

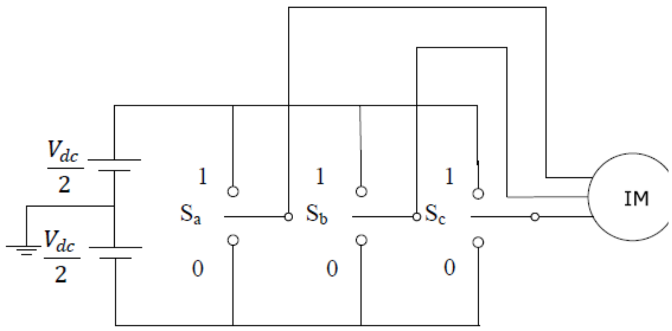

Fig 2 : Voltage source Inverter

Table 1: Switching states of a three phase VSI

State	S_a	S_b	S_c	Vector
0	0	0	0	V_1
1	1	0	0	V_2
2	1	1	0	V_3
3	0	1	0	V_4
4	0	1	1	V_5
5	0	0	1	V_6
6	1	0	1	V_7
7	1	1	1	V_8

The output of the VSI can be written in matrix form:

$$\begin{bmatrix} Va \\ Vb \\ Vc \end{bmatrix} = \frac{V_{dc}}{3} \begin{bmatrix} 2 & -1 & -1 \\ -1 & 2 & -1 \\ -1 & -1 & 2 \end{bmatrix} \begin{bmatrix} S_a \\ S_b \\ S_c \end{bmatrix}$$

By converting this V_a,V_b,V_c into V_d,V_q can be written in matrix as:

$$V_{dq0} = \frac{2}{3} \begin{bmatrix} 1 & \frac{-1}{2} & \frac{-1}{2} \\ 0 & \frac{\sqrt{3}}{2} & \frac{\sqrt{3}}{2} \\ \frac{1}{3} & \frac{1}{3} & \frac{1}{3} \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix}$$

B: Dynamic modeling of Induction Motor:

For DTC the Dynamic modeling of induction motor is done in the stator stationary frame of reference the equation is obtained as follows:

$$V_{ds} = R_s I_{ds} + \frac{d\psi_s}{dt} \qquad (1)$$

$$V_{qs} = R_s I_{qs} + \frac{d\psi_{qs}}{dt} \qquad (2)$$

$$\omega_r \psi_{ds} = R_r I_{qr} + \frac{d\psi_{qr}}{dt} \qquad (3)$$

$$\omega_r \psi_{qs} = R_r I_{dr} + \frac{d\psi_{dr}}{dt} \qquad (4)$$

$$\psi_s = L_s I_s + L_m I_r \qquad (5)$$

$$\psi_r = L_r I_r + L_m I_s \qquad (6)$$

C. Direct Flux Control:

The simplest method of stator flux estimation, where the machine terminal voltages and currents are sensed and from the stationary frame equivalent circuit the fluxes are computed. The estimated stator flux is given by the following equation:

$$\psi_{ds} = \int (V_{ds} - I_{ds} R_s) dt \qquad (7)$$

$$\psi_{qs} = \int (V_{qs} - I_{qs} R_s) dt \qquad (8)$$

The estimated Flux is:

$$\psi_s = \sqrt{(\psi_{ds2} + \psi_{qs2})} \qquad (9)$$

$$V_s = \frac{d\psi_s}{dt} \qquad (10)$$

D. Flux Hysteresis:

Flux hysteresis is two level controllers and has two digital output .

Stator flux error $\Delta\psi s = \psi sref - \psi s$

The flux is controlled according to the following equations

$|d\psi s| = 1$ if $|\psi s| \leq |\psi sref| - |\Delta\psi s|$: flux to be increased

$|d\psi s| = 0$ if $|\psi s| \geq |\psi sref| + |\Delta\psi s|$: flux to be decreased

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E. Direct Torque Control:

The electromagnetic torque is produced due to interaction of stator and rotor flux is given by the following equation:

$$T_e = \frac{3}{2}\frac{P}{2}\left(\frac{L_m}{L_s L_r}\right)\psi_s \psi_r \qquad (11)$$

$$T_e = \frac{3}{2}\frac{P}{2}\left(\frac{L_m}{L_s L_r}\right)\psi_s \psi_r \sin\gamma \qquad (12)$$

F. Torque Hysteresis:

The Torque hysteresis is three level controllers and has three digital outputs:

Torque error $\Delta T_e = T_{eref} - T_e$

$|dT_e| = 1$ if $|T_e| < |T_{eref}| - |\Delta T_e|$: Torque to be increased

$|dT_e| = -1$ if $|T_e| > |T_{eref}| + |\Delta T_e|$: Torque to be decreased

$|dT_e| = 0$ if $|T_{eref}| - |\Delta T_e| \le |T_e| \le |T_{eref}| + |\Delta T_e|$: Torque to remain unchanged.

Table2: voltage vector selection

$d\psi$	dTe	S(1)	S(2)	S(3)	S(4)	S(5)	S(6)
1	1	V_2	V_3	V_4	V_5	V_6	V_1
	0	V_7	V_0	V_7	V_0	V_7	V_0
	-1	V_6	V_1	V_2	V_3	V_4	V_5
0	1	V_3	V_4	V_5	V_6	V_1	V_2
	0	V_0	V_7	V_0	V_7	V_0	V_7
	-1	V_5	V_6	V_1	V_2	V_3	V_4

When the flux hysteresis give 1 and Torque Hysteresis give 1 and the sector is 1 then voltage vector (v_2) is obtain this is obtain by following table :

Table 3: General table for voltage vector k

K sector	Increases	Decreases
Stator flux	V_k, V_{k-1}, V_{k+1}	$V_{k+2}, V_{k+3}, V_{k-2}$
Torque	V_k, V_{k+1}, V_{k+2}	$V_{k+3}, V_{k-2}, V_{k-1}$

III FUZZY LOGIC CONTROLLER:

The fuzzy logic controller is an artificial intelligence technique. The unique property of Fuzzy logic is that it is tolerance for imprecision[9] that means if the system input is not precise it still give the more accurate output.

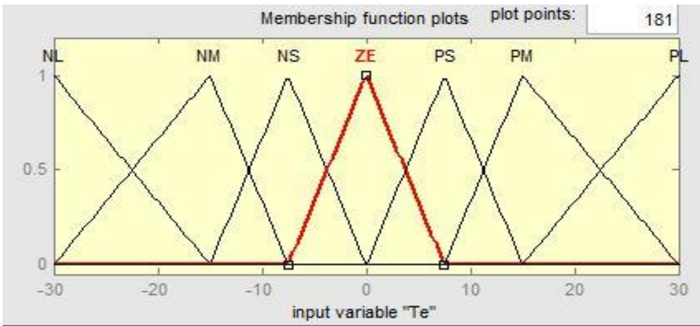
The fuzzy logic can be design for any control system in the following step:

1. Fuzzyfication: Membership functions used to graphically describe a situation.
2. Evaluation of Rule: Application of the fuzzy logic rules.
3. Diffuzfiication: Obtaining the crisp results.

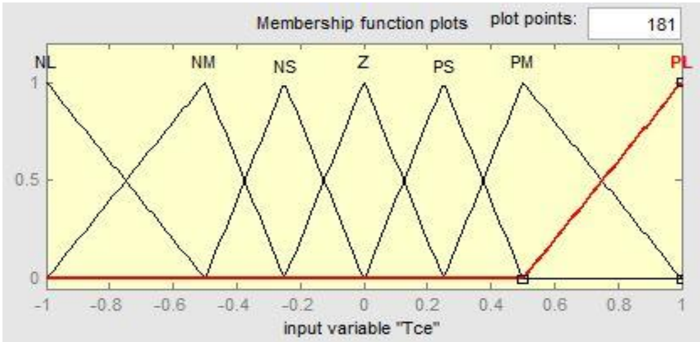
   A FLC convert the linguistic control strategy into the automatic control strategy.

In proposed model the two inputs for Fuzzy Logic is Torque error and change in Torque error and its output is torque duty.

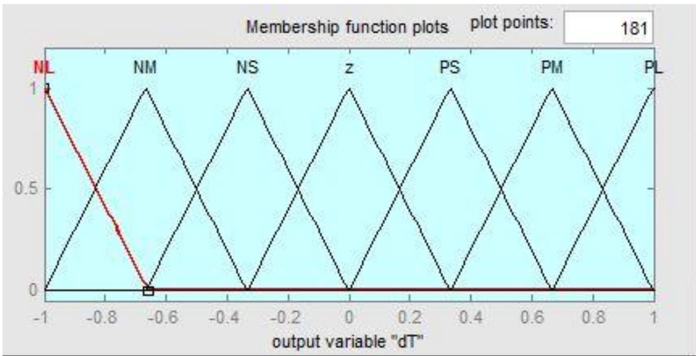
.Consider Fuzzy speed control system , where the input signals are E and CE and the output is Torque reference are Fuzzified by assigning corresponding member ship functions to each signal .



(a) Fuzzy Input variable rate of Torque error



(b) Fuzzy Input variable change in torque error



(c) Output variable

In Fuzzy membership function there are two input variable and each input variable have seven linguist values, so 7x7=49 Fuzzy control rule are in the Fuzzy reasoning:

Table 4: Fuzzy Logic Control Rule

TEC / TE	NL	NM	NS	Z	PS	PM	PL
NL	NL	NL	NL	NL	NM	NS	Z
NM	NL	NL	NL	NM	NS	Z	PS
NS	NL	NL	NM	NS	Z	PS	PM
Z	NL	NM	NS	Z	PS	PM	PL
PS	NM	NS	Z	PS	PM	PL	PL
PM	NS	Z	PS	PM	PL	PL	PL
PL	Z	PS	PM	PL	PL	PL	PL

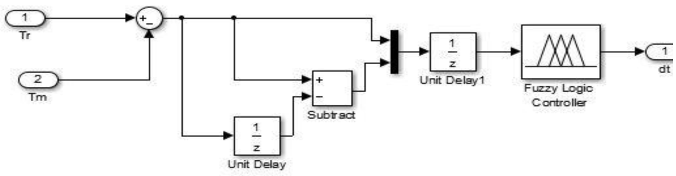


Fig 3 :MAT lab /simulink model for Fuzzy Logic Controller.

IV SIMULATION AND RESULT

The three phase induction motor drive model using Direct Torque Control method is simulated by using the Matlab/simulation.

A MATLAB Simulation is developed to study the performance of the conventional DTC and DTC with Fuzzy Logic controller for 4 poles Induction Motor torque control, and also a SIMULINK model is developed and simulated for the same and verified. Constant torque and flux commands of 1.5 Nm and 1Wb were used

Table5.1: Parameter of the induction motor Drive

Parameter	Nominal Value
Stator Resistance (Rs)	1.57Ω
Rotor Resistance (Rr)	1.21Ω
Mutual Inductance(Lm)	165mH
Stator Inductance (Ls)	17mH
Rotor Inductance (Lr)	17mH
Inertia (J)	.025Kg.m^2
Dc voltage	540 V

The simulation Result of Conventional and proposed DTC method at the following Fig:

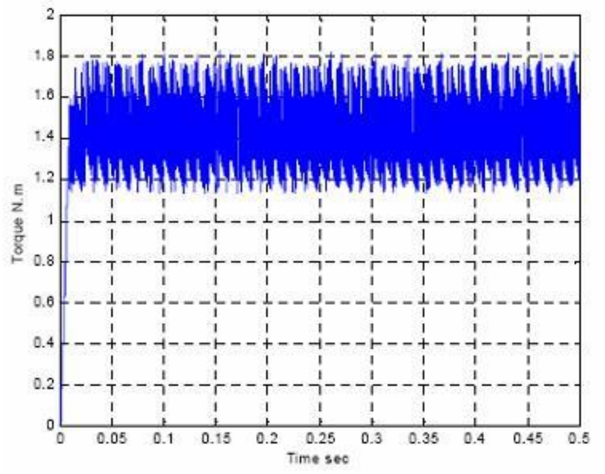


Fig 4: Torque waveform for conventional DTC

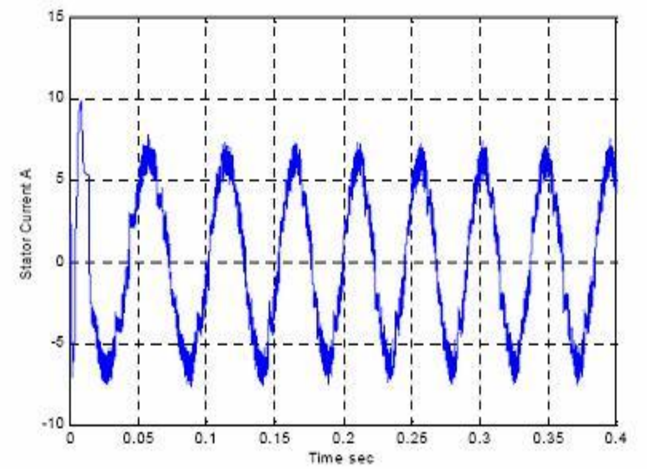


Fig 5 : stator current

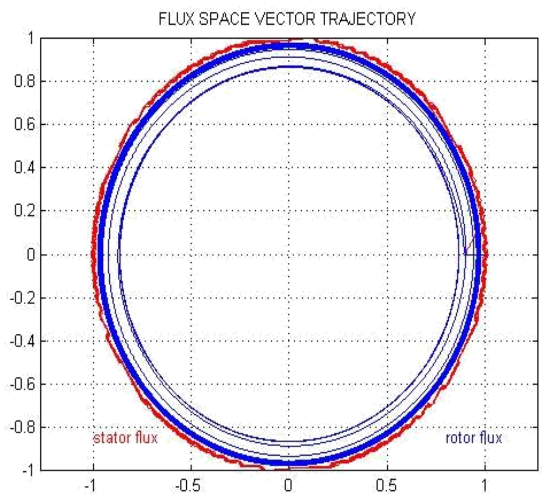


Fig 6:Flux Trajectory for conventional DTC

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Simulation result using Fuzzy logic controller

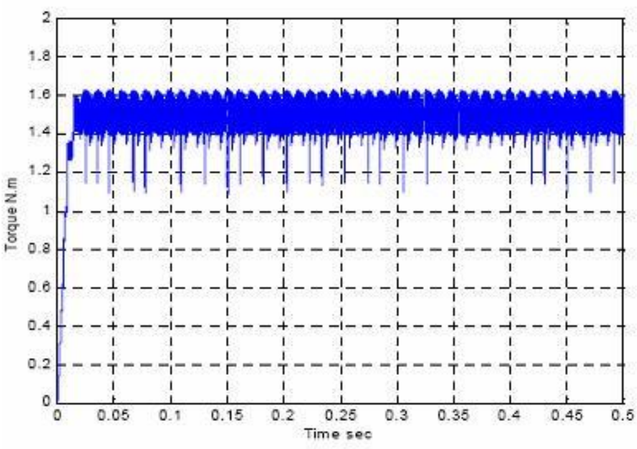

Fig7: Torque of induction motor using DTC with Fuzzy Logic controller.

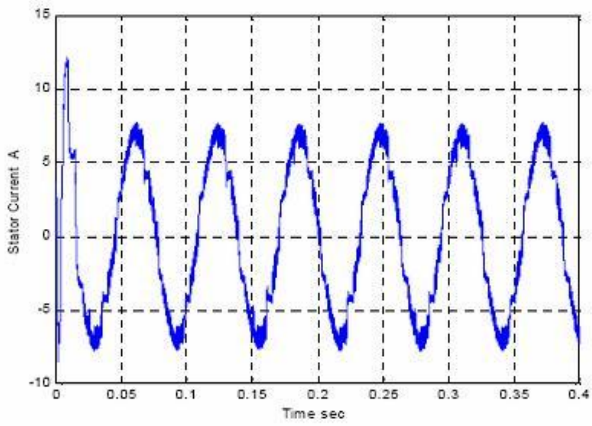

Fig 8: Stator current using fuzzy logic

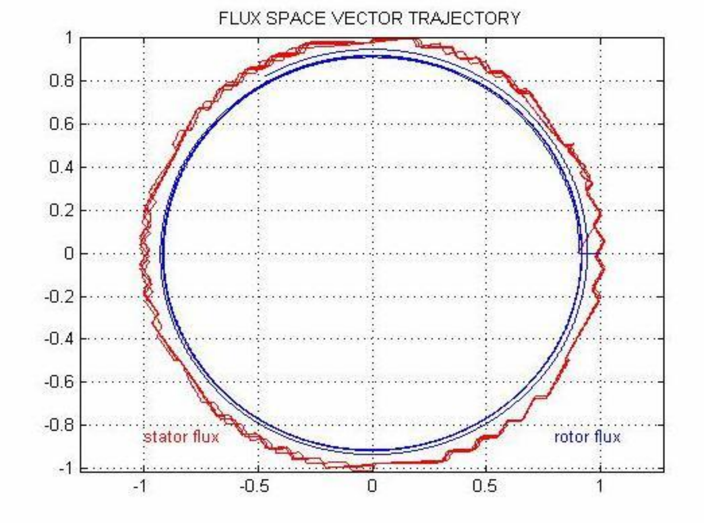

Fig 9: Flux trajectory of DTC using fuzzy logic

V CONCLUSION

In this paper the Fuzzy Logic is used to control the ripple in Torque , stator current and flux trajectory of Induction Motor Drive based on Fuzzy logic Technique. The simulation result shows that the ripple in torque of convention DTC is about 0.6 Nm while using fuzzy logic it reduces to 0.2Nm.As compared to conventional DTC Fuzzy Logic control Method is easy to implement and the steady state performance for ripple are considerably improve.

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