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Simulation of VSI-Fed Variable Speed Drive Using PI-Fuzzy based SVM-DTC Technique

B.Hemanth Kumar[1], Dr.G.V.Marutheshwar[2]
PG Student,EEE S.V. College of Engineering Tirupati
Senior Professor,EEE dept. S.V.College of Engineering Tirupathi

ABSTRACT: *Direct Torque Control (DTC) is the first technology to control the "real" motor control variables of torque and flux. It is a control method that gives an excellent torque response for A.C Drives. This paper provides an approach about the Fuzzy logic control (FLC) based Space Vector Modulation (SVM), on the direct torque controlled Induction Motors and aim of the approach is to overcome high torque ripple disadvantages of PI based Space Vector Modulation. Proposed method gives an optimum flux and torque ripple at steady state condition and fast dynamic torque response. In order to test and compare the proposed FLC based SVM DTC method with PI based SVM DTC method simulations, in Matlab/Simulink have been carried out in different working conditions. The simulation results showed that the proposed method gives the better improvement in the torque and flux ripples when compared to the PI based SVM DTC method.*

KEYWORDS: *Direct torque control (DTC), Fuzzy logic control (FLC), Space vector modulation (SVM), Induction motor (IM).*

I. INTRODUCTION

The induction machine is one of the most widely used machines in industrial applications due to its high reliability, relatively low cost and robust construction [1]. High performance electrical drives require decoupled torque and flux control. This control is offered in a dynamic fashion by the Direct torque control. In many applications, Direct torque control (DTC) of an induction motor is well- known control method which provides fast dynamic response compared with other control methods like field oriented control (FOC). The DTC has been proposed for induction motor control in 1985 by Takahashi [1] and similar idea that the name of Direct Self Control devoloped in 1988 by Depenbrock [2]. Over the past years, the DTC has gained more attention due to its advantages like simple control structure, robustness to the parameters variations, fast dynamic response, not need to current regulators...etc. However, DTC has still some disadvantages and they can be summarized as follows; high current and torque ripples, difficulty to control torque and flux at very low speed, variable switching frequency behaviour and high sampling frequency needed for digital implementation.

On the other hand, intelligent control methods like fuzzy logic have been explored by several researchers for its potential in the design process. The FL has gained great attention in the every area of electromechanical devices control due to no need mathematical models of systems unlike conventional controllers [5]. A fuzzy logic controller is used to select voltage vectors in conventional DTC in some applications. In parameter estimation applications, a fuzzy logic stator resistance estimator is used and it can estimate changes in stator resistance due to temperature change during operation. For duty ratio control method, a fuzzy logic controller is used to determine the duration of output voltage vector at each sampling period [8]. These fuzzy logic controllers can provide good dynamic performance and robustness.

In this paper, to reduce the torque ripples of the induction motor on the DTC method, a new approach has been proposed which named as, fuzzy logic based space vector modulation method (FL-SVM). The fuzzy logic controller [11], in this proposed method, speed and unit delay speed errors as input and produces an output to minimize flux and torque errors. The numerical simulation studies have been performed with Matlab/Simulink to know the performance testing of the proposed control method. In the final section, we conclude the paper and draw the outlines of the future work

II. PRINCIPLE OF DIRECT TORQUE CONTROL

`The basic functional blocks used to implement the DTC scheme in an induction motor is shown in Fig. 1. Three phase AC supply is given to the diode bridge rectifier which produces a DC voltage. A high value dc link capacitor is used to reduce the ripple content in the DC voltage. The filtered DC is the power supply to the inverter switches. The IGBT inverter switches are controlled by the direct torque control algorithm. The output of the inverter is connected to the stator terminals of induction motor.

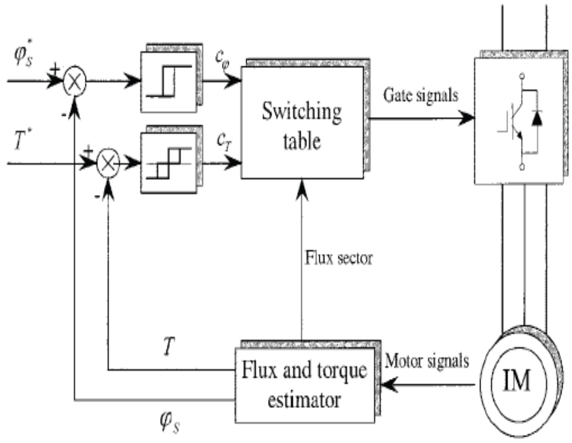

Fig 1: Block diagram of DTC

III. TORQUE AND FLUX ESTIMATOR

The feedback flux and torque are calculated from the machine terminal voltages and currents. The computation block also calculates the sector number in which the flux vector lies. The phase voltage and currents in stationary reference are given as

$$V_{s\alpha} = V_a \quad and \quad V_{s\beta} = \frac{-1}{\sqrt{3}}(V_a + 2V_b)$$

$$I_{s\alpha} = I_a \quad and \quad I_{s\beta} = \frac{-1}{\sqrt{3}}(I_a + 2I_b)$$

The components of stator flux is given by

$$\varphi_{s\alpha} = \int(V_{s\alpha} - R_s I_{s\alpha})dt$$

$$\varphi_{s\beta} = \int(V_{s\beta} - R_s I_{s\beta})dt$$

The magnitude of the stator flux can be estimated by

$$\varphi_s = \sqrt{\varphi_{s\alpha}{}^2 + \varphi_{s\beta}{}^2}$$

The flux vector zone can be obtained using the stator flux components.By using the flux components, currentcomponents and
IM number of poles, the electromagnetic torque can be calculated by

$$T_e = \frac{3}{2}\frac{P}{2}(\varphi_{s\alpha} I_{s\beta} - \varphi_{s\beta} I_{s\alpha})$$

B. Torque and Flux Controller:

The instantaneous values of flux and torque are calculated from stator variables by using flux and torque estimator. The command stator flux and torque magnitude are compared with their respective estimated values and the errors are processed by the hysteresis band controllers. The flux loop controller has two levels of digital output according to following
equations.

$$H_\varphi = 1 \text{for} E_\varphi > +HB_\varphi$$

$$H_\varphi = -1 \text{for} E_\varphi > -HB_\varphi$$

Where 2HB is the total hysteresis bandwidth of the controller. The actual stator flux is constrained within the hysteresis band and tracks the command flux. The torque control loop has three levels of digital output represented by the following equations.

$$H_T = 1 \text{for} E_T > +HB_T$$

$$H_T = -1 \text{for} E_T > -HB_T$$

$$H_T = 0 \text{for} -HB_T < E_T < +HB_T$$

In DTC method, stator flux rotate trajectory divided six region and well-defined of stator flux region is directly affects on control performance. The stator flux α-β components that calculated can be use the defining of the stator flux region as given in below equation

$\theta = arctan\left({}^{\psi_{s\alpha}}/_{\psi_{s\beta}} \right)$ These observed values of the flux and the torque errors are compared to reference the flux and the torque values and the resultant errors are applied to the hysteresis comparators as inputs. Two different hysteresis comparators, as flux and torque comparators, generate other control parameters on the DTC method. According to the hysteresis comparators outputs, the observed angle of flux linkage and using a switching table, optimum voltage vectors are selected and applied to the inverter.
The objective of space vector pulse width modulation technique is to obtain the demanded output voltage by instantaneously combination of the switching states corresponding the basic space
vectors

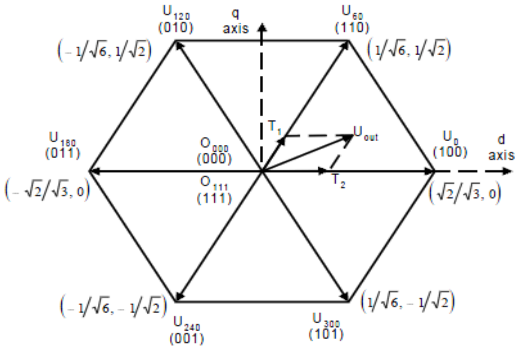

Fig 2: Voltage switching vectors

IV. BASICS OF THE FUZZY LOGIC CONTROLLER

Fuzzy logic control (FLC) is a control algorithm based on a linguistic control strategy which tries to account the human's knowledge about how to control a system without requiring a mathematical model [11]. The approach of the basic structure of the fuzzy logic controller system is illustrated in Fig

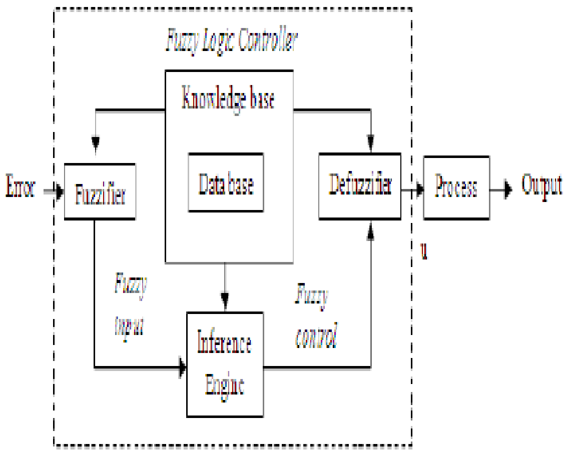

Fig 3: Structure of fuzzy logic controller

The design of a Fuzzy Logic Controller requires the choice of Membership Functions. The membership functions should be chosen such that they cover the whole universe of discourse. It should be taken care that the membership functions overlap each other. This is done in order to avoid any kind of discontinuity with respect to the minor changes in the inputs. To achieve finer control, the membership functions near the zero regions should be made narrow. Wider membership functions away from the zero region provides faster response to the system. Hence, the membership functions should be adjusted accordingly. After the appropriate membership functions are chosen, a rule base should be created. It consists of a number of Fuzzy If-Then rules that completely define the behaviour of the system. These rules very much resemble the human thought process, there by providing artificial intelligence to the system. Here 7x7 rule base are used, it has 49 rules .

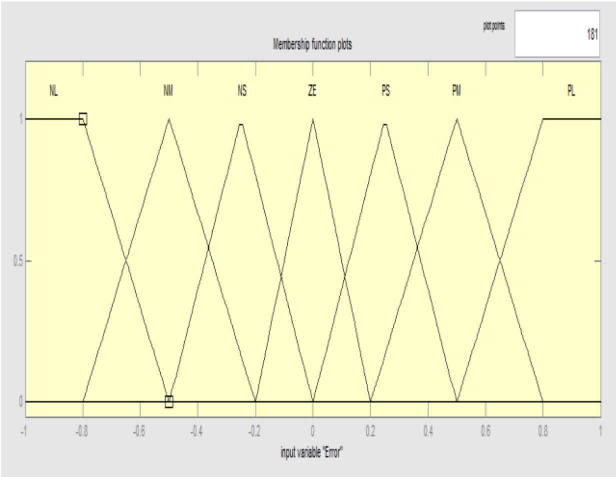

Fig 4: Input error membership functions

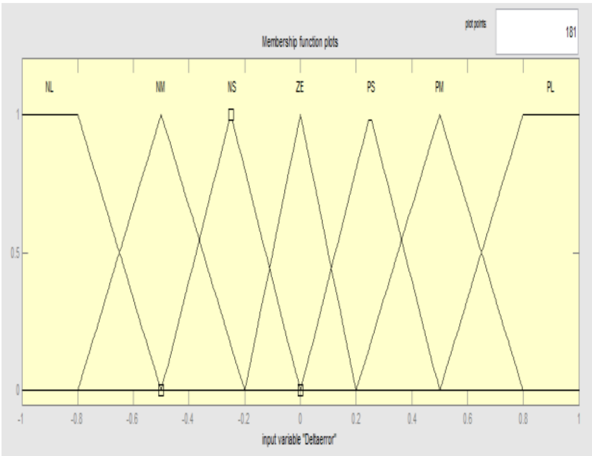

Fig 5: Input Deltaerror membership functions

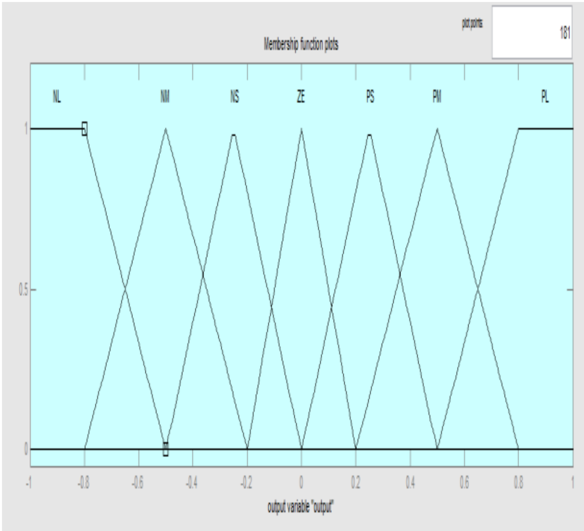

Fig 6: Output membership functions

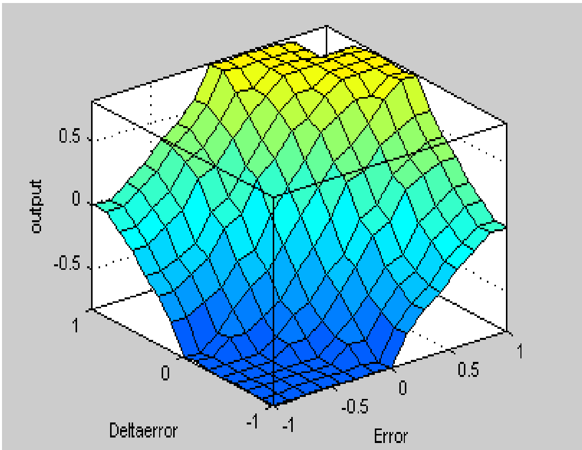

Fig 7: Surface of the FLC

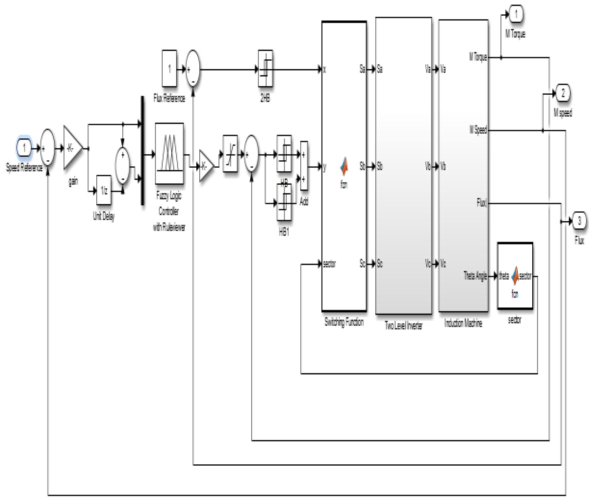

Fig 8: The Simulink block diagram for the proposed method (SVM DTC using Fuzzy controller)

V. SIMULATION RESULTS

In this section, the software Matlab/Simulink is used to simulate the whole DTC system to examine the performance of induction motor. The simulation conditions is given as: the speed is 150r/s and the reference flux is 1.0 Wb the initial load torque is 0 N.m shown in Fig (9) and Fig (12 , when at 0.5second, the load torque set at 10 Nm; simulation time is 1.0 second as shown in Fig (10) and Fig (13). Fig(11) and Fig(14) shows the the speed is 150r/s and the reference flux is 1.0 Wb, , when at 0.5second, the load torque set at 10 Nm and at 0.75 sec the load torque set at -20Nm. Fig (16) and Fig(19) shows the stator current trajectory which give a good current response but much faster response with fuzzy controller. Fig (17) and Fig (20) shows the stator flux trajectory which gives a good response with a circular shape

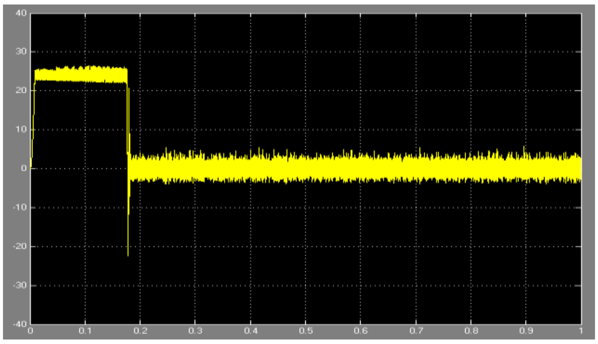

Fig 9: No load torque response for PI based SVM DTC at constant speed 150r/s.

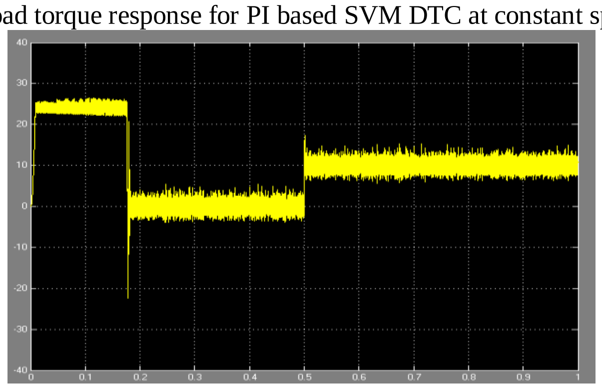

Fig 10: load torque response of 10 Nm at 0.5 sec for PI based SVM DTC at constant speed 150r/s.

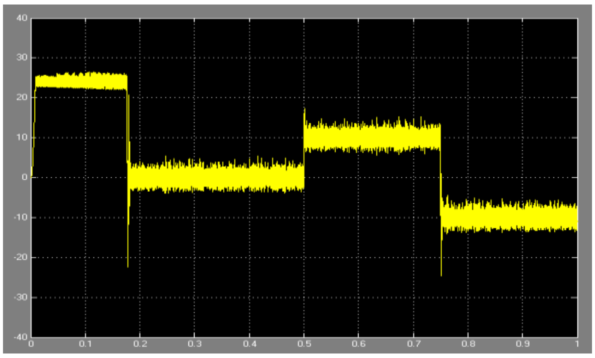

Fig 11: load torque response of 10 Nm at 0.5 sec and -20 Nw at 0.75 sec for PI based SVM DTC at constant speed 150r/s.

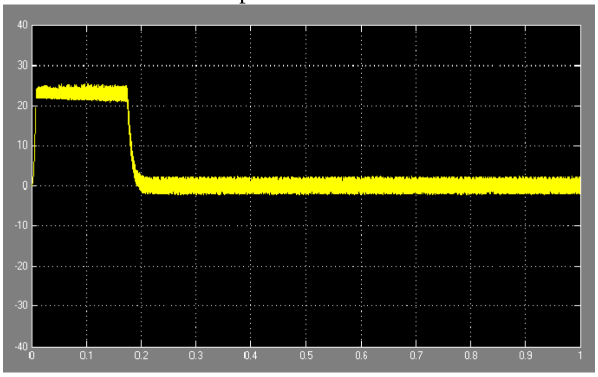

Fig 12: No load torque response for Fuzzy based SVM DTC at constant speed 150r/s.

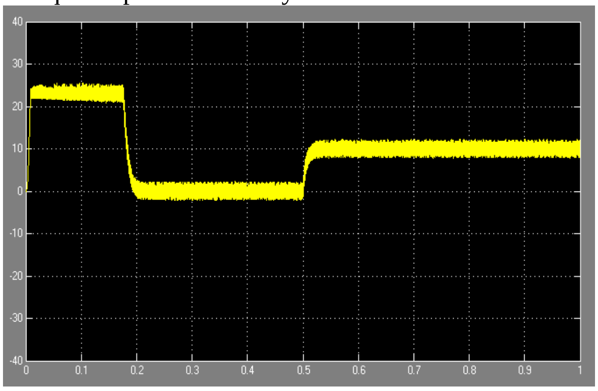

Fig 13: load torque response of 10 Nm at 0.5 sec for Fuzzy based SVM DTC at constant speed 150r/s.

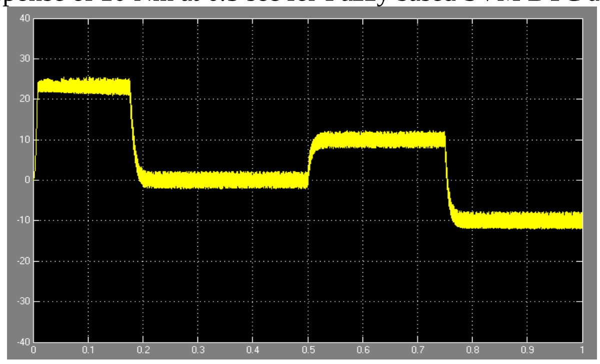

Fig 14: load torque response of 10 Nm at 0.5 sec and -20 Nw at 0.75 sec for Fuzzy based SVM DTC at constant speed 150r/s..

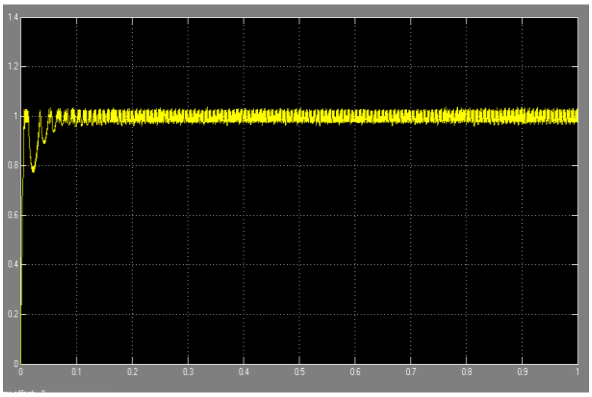

Fig 15: Flux response for PI based SVM DTC.

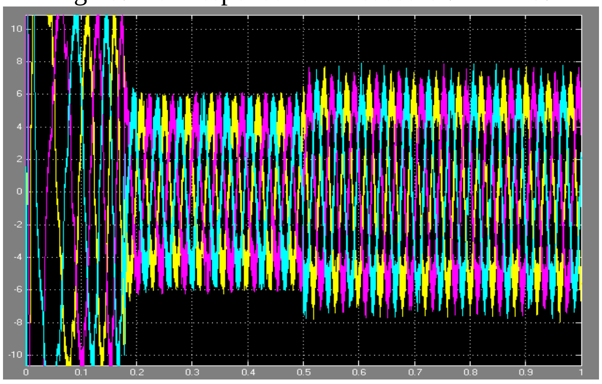

Fig 16:Stator armature current PI based SVM DTC.

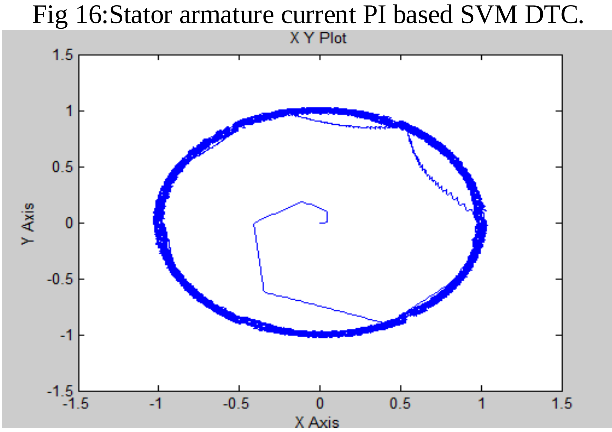

Fig 17: Stator flux trajectory PI based SVM DTC.

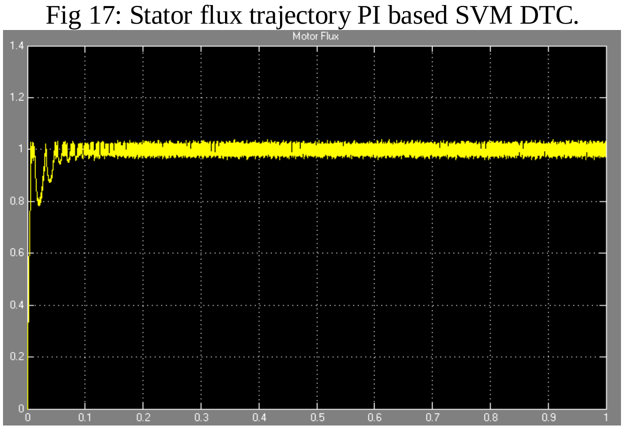

Fig 18: Flux response for Fuzzy based SVM DTC.

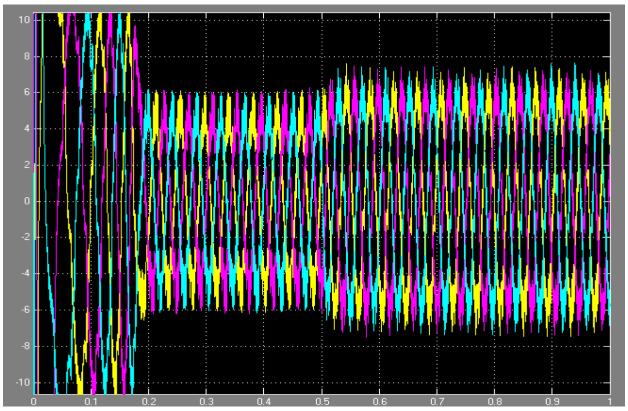

Fig 19: Stator armature current Fuzzy based SVM DTC

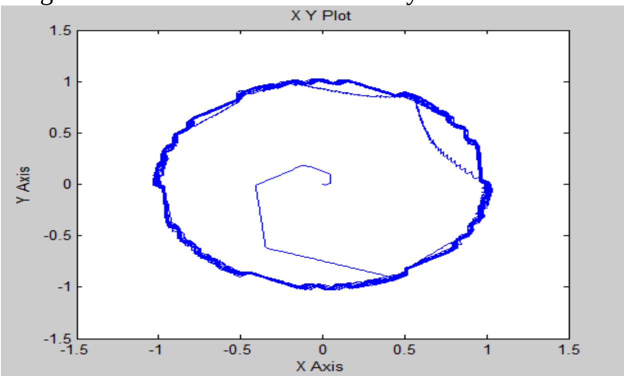

Fig 20: Stator flux trajectory Fuzzy based SVM DTC

VI. CONCLUSION

The direct torque control of induction motor with fuzzy logic controller is investigated in this paper. DTC of induction motor with fuzzy logic controller is compared with PI controller. It has been observed that the torque and the stator flux ripples are significantly reduced in fuzzy controller. Other improvements were observed in fuzzy controller are the reduction in phase current distortion, fast torque response and increase in efficiency of the drive. Therefore, SVM-DTC may be an excellent solution for general purpose IM drives in a very wide power range. In conclusion, it is believed that the DTC principle will continue to play a strategic role in the development of high performance drives.

REFERENCES

[1]. Joachim Bocker,Shashidhar Mathapati, "State Of Art Of Induction Motor", IEEE Transactions On Power Delivery, vol.14, no.2, october 2007.
[2]. B Karanayil, M F Rahman,C Grantham, "A Complete Dynamic Model For PWM VSI Fed Rotor Flux Oriented Vector Controlled Induction Motor Drive Using Simulink", IEEE Transactions On Power Delivery, vol.14, no.2, october 2006.
[3]. A A Ansari,D M Deshpande, "Mathematical Model Of Asynchronous Machine in MATLAB/Simulink", IEEE Transactions On Power Delivery, vol.14, no.2, October 2010.
[4] Dal Y Ohm , "Dynamic Modelling Of Induction Motor For Vector Control", IEEE Transactions On Power Delivery, vol.14, no.2, october 2008.
[5] Ernesto,Ruppert Filho,Ronaldo Martins De souza, "Three phase induction motor dynamic mathematical model ", IEEE Transactions On Power Delivery, vol.14, no.2, october 1997.
[6] R J Lee,P Pillay,R G Harley , "D,Q Reference frame for simulation of induction motor", IEEE Transactions On Power Delivery, vol.14, no.2, october 1984.
[7] Narasimham PVRL,Sarma VVRS Vaigil Kumar E,"A Sector Advanced Technique To Improve Dynamic Response Of DTC Of Induction Motor", IEEE Transactions On Power Delivery, vol.14, no.2, october 2010.
[8] Narayanan Prasad Gupta,Preeti Gupta, "Performance Analysis Of DTC Of PMSM Drive Using SVPWM Inverter", IEEE Transactions On Industrial Applications, vol.33, no.3, pp. 436-494, July 2012.
[9] Dipti H Ganatra,Saurabh N Pandya, "Torque Ripple Minimization In DTC Based Induction Motor Drive Using fuzzy logic" IEEE Transactions On Power Delivery, vol.14, no.2,july 2012.

[10] Yukinoi Inour,Shigro Morimoto, Masayuki Sanada, "Control Method Suitable For DTC Based Motor Drive System Satisfying Voltage And Current", IEEE Transactions On Power Delivery, vol.14, no.2, October 2012.
[11] Gilberto c d souse, Bimal K Bose, "A fuzzy set theory based control of phase controlled converter DC motor drive",IEEE Transactions On Power Delivery, vol.14, no.2,july 2011.
[12] Zuraida Binti Zainol, "Development of simulink model of DTC of induction motor", IEEE Transactions On Power Delivery, vol.14, no.2, october 2005.
[13] Wu Tao,Zhau Liang, "Simulation Of Vector Control Frequency Converter Of Induction Motor Based On MATLAB/simulink", IEEE Transactions On Industrial Applications, vol. 16, no.2, december 2011.
[14] M Lakshmi Swarupa,G Tulasi Ram Das,P V Raj Gopal, "Simulation And Analysis of SVPWM Based 2-level And 3-level Inverter of DTC of Induction Motor", IEEE Transactions On Power Delivery, vol.14, no.2, October 2011.
[15] C J, Bonanno Lizen Longya Vu, "A Direct Field Oriented Induction Motor Drive With Robust Flux Estimator For Position Sensorless Control",IEEE Transactions On Power Delivery, vol.14, no.2, october 1995.