Enhanced Direct Torque Control of Induction Motors Using Constant Switching Frequency Torque Controller and Fuzzy Logic Control

D. Bharathi[1], G. Ismayel[1], T. Sivaram[1]

[1]Assistant Professor, Dept. of EEE, Malla Reddy Engineering College and Management Sciences, Medchal, Hyderabad, India

ABSTRACT

The Direct Torque Control (DTC) methods for AC machines are commonly utilized in many variable-speed drives, especially in cases where torque control is more desired than speed control. Two major problems that are usually related to DTC drives are: 1) switching frequency that varies with operating conditions; and 2) high torque ripple. To solve these problems and, at the same time, improve the simple control structure of DTC, a constant switching frequency torque controller is proposed to replace the conventional hysteresis-based controller. The best features of the voltage source inverter (VSI) and the direct current (DTC) method are combined to create the right voltage vectors when the input power factor is 0.9. The results show that the system's dynamic response is of high quality and reliability, and they also show that both steady-state and transient motor ripple torque are kept to a minimum. We suggest a way to use VSI-based DTC in IM drives to choose the right switching vectors for controlling torque with small changes in the stator flux within the hysteresis band. This paper presents a novel control scheme based on a fuzzy logic controller (FLC). This paper reviews the research and development in direct torque control of VSI-fed IM. Such a review helps the highly effective control strategies for AC machines to provide very fast torque and flux control. In this technical context, an overview of VSI-fed induction motors has been carried out based on reports from the literature presented in the past two decades.

Key words: *Direct torque control (DTC) Fuzzy logic controller (FLC) Induction motor drive (IMD) Voltage source inverter (VSI).*

1. INTRODUCTION

INTRODUCTION been particularly used in speed control applications. The Induction motors are today a standard for industrial using various speed controllers has been analysed and electrical drives and high performance variable speed drive discussed for step variation in reference speed and application have a series of usages. In general, there are reference load torqueses. High dynamic performance of IM two methods that can be used to solve the problem of drive is obligatory in more applications of today's variable switching frequency: 1) by using variable automatic control machine [8]. VSIs are used to regulate hysteresis bands to maintain a constant switching the speed of three-phase squirrel cage IM (SCIM) by frequency and 2) by performing the switching at regular changing the frequency and voltage and consist of input intervals [1-7]. Thereare many ways for speed control rectifier, DC link and output converter. They are available of IMs fed through the VSIs using various modulations for low voltage range and medium voltage range. The techniques. Researchers, scientist and engineers are basic action involved in adjustable speed control of IM is continuously inventing the new schemes and methods to apply a variable voltage magnitude and variable that cover the speed control requirements of the drive frequency to the motor so as to obtain variable speed Advanced control techniques such as fuzzy, neuro-fuzzy, operation. Both the VSI and Current Source Inverter (CSI) genetic algorithm, sliding mode control, etc. have also are used in adjustable speed AC drives [9-12]. Figure 2 show the block diagram block diagram of VSI-fed IM drive using P, PI and PID controllers' technique in this theory. DTC technique for induction motors has been proposed. The main advantages of DTC are robust and quick torque response, no need for coordinate transformation, no requirements for PWM pulse generation and current Fuzzy logic control has emitted its staunchness and has been extensively researched and used as one of the intelligent control methods in control side [13, 14, 15]. The new SVM-DTC strategy uses fuzzy logic controller substitute the original PI controller. In this paper, a new Fuzzy DTC control for matrix converter is proposed which permutated under the constraint of unity input power factor, the generation of the voltage vectors required to implement the DTC of three phase induction motor.

2. INDUCTION MOTOR

One of the most important features of a traction motor is its lower weight and dimension compared with conventional motors. The other difference is its special design to tolerate long term overloads. Favourable characteristics of electric traction motor are: High density of torque and power Vast constant power operation region High efficiency Minimum number of sensors

Maximum torque of three phase induction motor is as follows:

$$T_p = \frac{3P}{\omega_s} V_s^2 \frac{R_r / S}{(R_r / S)^2 + (\omega_s L_r)^2} \quad (1)$$

The motor dynamic torque equation is as follow:

$$T_m - T_e = -J(d\omega / dt) \quad (2)$$

Where J is the moment of the inertia and w is the rotor speed. The torque-speed characteristic of induction motor is shown in Fig. 1. The torque-speed characteristic contains generating, motoring and braking mode of operation. Traction motor operates in generating mode during braking or speed reduction, if the stator flux vector lags behind the rotor flux vector. Considering this issue, traction motor should not be separated from the inverter during energy regeneration; because this results in loss of stator flux vector and hence the linkage flux decreases to zero rapidly. Therefore, an appropriate driver should be provided in which by applying a suitable switching pattern, the stator flux vector locates in a suitable position related to the rotor flux vector. Thus, an appropriate negative electromagnetic torque is produced for energy regeneration. With regard to (2), speed increases and decreases when the difference between mechanical and electromagnetic torque is less and more than zero, respectively.

3. MODIFIED DIRECT TORQUE CONTROL

In modified DTC, to adjust switching frequency at a fixed value and take advantages of SVM, hysteresis controllers and look-up table are replaced by SVM. This modulation method has advantages such as fixed switching frequency, decreasing power loss and torque ripple, softer starting and lower sampling frequency in comparison with the method uses hysteresis controllers and look-up table [8-9].

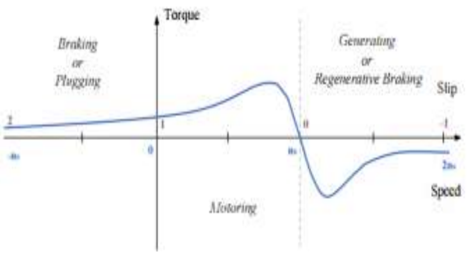


Fig 1Torque characteristics of Induction Motor

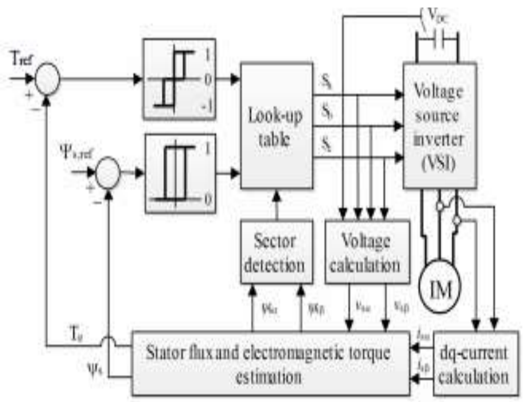


Fig 2 Block diagram of DTC.

There are several methods which implement SVM-DTC. Three main methods i.e. closed loop torque control, closed loop flux and torque control in polar coordinates and closed loop flux and torque control in the stator flux coordinates are studied. These schemes use flux and/or torque feedback and pass their error relative to reference values through appropriate controllers to generate reference voltage vector as SVM block input [9-10].

A. SVM-DTC based on closed loop torque control:

Block diagram of SVM-DTC based on closed loop torque control is shown in Fig. 3. This scheme is designed based on the following equation: - Ll ii/s R ' VS =--+ sis Llt (3) In order to use SVM, stator reference voltage vector should be generated by means of the controllers before modulator. Magnitude and angle of the voltage vector depends on the difference between estimated and reference values. If the error of stator voltage and flux vector could be estimated, the reference voltage vector is generated by (3). Fig. 4 shows the flux vectors in vector space. Referring to Fig. 4, the reference flux can be calculated as: (4) Where Ilf/scl is reference flux and LlOIf/ is output of PI controller.

B. SVM-DTC based on closed loop flux and torque control in polar coordinates:

In the previous method, torque is controlled in closed loop, but there is no control on flux and hence it is processed in open loop. Therefore, SVM-DTC based on closed loop flux and torque control in polar coordinates was introduced. In this method the flux is controlled in a closed loop structure, as it is shown in Fig. 3.

C. SVM-DTC based on closed loop flux and torque control

In stator flux coordinates Two previous described schemes are designed based on (3), in other words, a type of differentiator has been used in their structures. Therefore, these schemes are too sensitive to disturbances and are more susceptible to instability in case of fault occurrence in control loop. These problems lead to propose SVM-DTC based on closed loop flux and torque control in stator flux coordinates. Block diagram of this scheme is shown in Fig. 4.

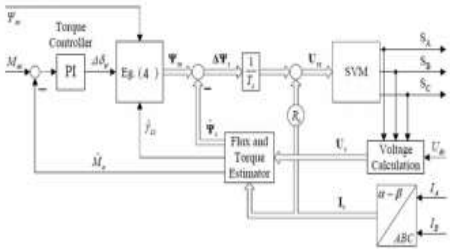


Fig 3 Block Diagram of SVM-DTC based on closed loop torque control.

This scheme uses two PI controllers and a coordination transformation block. This method does not have the problems of previous methods and is more appropriate for industrial applications, but it is a little complicated in structure compared with the previous methods. Reference voltage vector is generated by means of PI controllers output and the angle of stator flux vector.

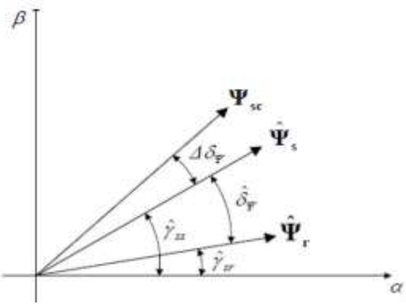


Fig 4 Flux vector diagram

4. 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 are given as: the speed is 100r/min and the reference flux is 0.9 Wb the initial load torque is 20N.m, when at 0.2 second, the load torque set at 30 Nm; simulation time is 0.6 second. Fig. 4, Fig. 5, and Fig. 6 shows the speed, torque and stator current using DTC with PI controller. Fig. 4 shows the speed response in which the speed reaches steady state at 100 rev/min at 0.13, but with that using fuzzy controller speed reaches steady state much faster as shown in Fig. 8. Fig. 5 and Fig. 9 shows the torque response which reaches 20 Nm much faster with fuzzy controller. Fig. 7 and Fig. 10 shows the stator current trajectory which give a good current response but much faster response with fuzzy controller.

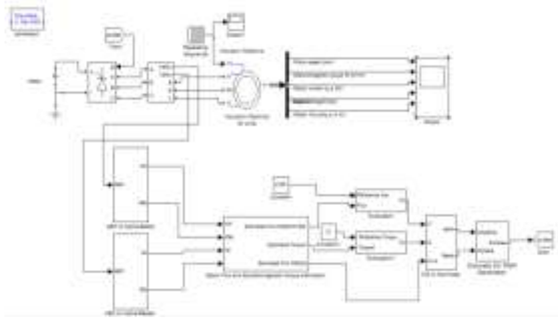


Fig. 4: Simulink model of proposed system

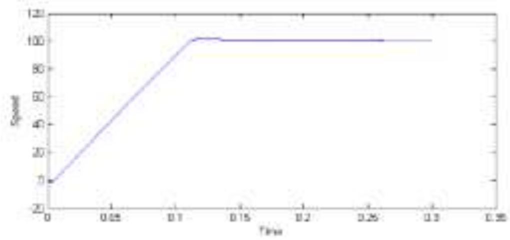


Fig. 5: Speed response using PI controller

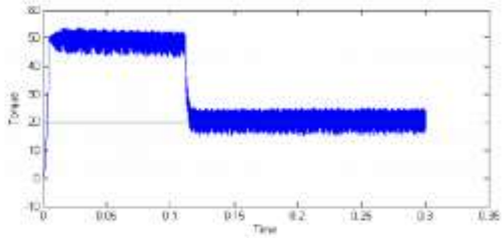
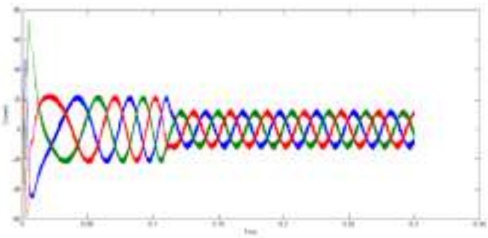


Fig. 6: Torque response using PI controller



Fi. 7: Stator current trajectory using PI controller

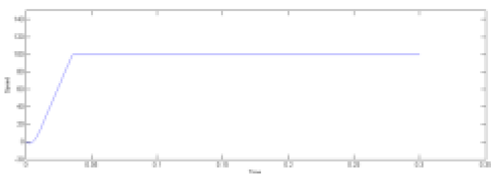


Fig. 8: Speed Response using Fuzzy controller

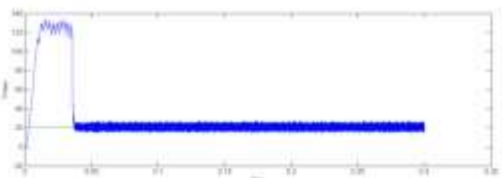


Fig. 9: Torque response using fuzzy controller

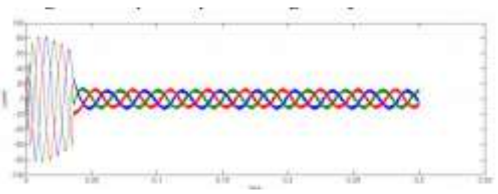


Fig. 10: Stator current trajectory using Fuzzy controller

5. 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 and a constant switching frequency is achieved in fuzzy controller. Other improvements observed in fuzzy controller are the reduction in phase current distortion ,fast torque response and increase in efficiency of the driv**e**.

REFERENCES

[1] T. Sutikno. N. R. N. Idris. and A. Jidin. "A review of direct torque control of induction motors for sustainable reliability and energy efficient drives." Renewable and Sustainable Energy Reviews. vol. 32, pp. 548-558, Apr. 2014.

[2] F. Rahman and R. Dutta, "AC Motor Control Applications in Vehicle Traction," in AC Electric Motors Control, John Wiley & Sons Ltd, 2013,pp. 453-486.

[3] Sergaki, E.S.; Moustaizis, S.D., "Efficiency optimization of a direct torque controlled induction motor used in hybrid electric vehicles," Electrical Machines and Power Electronics and 2011 Electromotion Joint Conference (ACEMP), 20111nternational Aegean Conference on , vol., no., pp.398,403, 8-10 Sept. 2011

[4] Zhongbo Peng; XueFeng Han; Zixue Du, "Direct Torque Control for Electric Vehicle Driver Motor Based on Extended Kalman Filter," Vehicular Technology Conference Fall (VTC 201 a-Fall), 2010 IEEE 72nd , vol., no., pp.I,4, 6-9 Sept. 2010

[5] Rehman H, Longya X. Alternative energy vehicles drive system: control, flux and torque estimation, and efficiency optimization. IEEE Trans Veh Technol 2011; 60:3625-34.

[6] Rongmei, P. L., et al. "A Novel Fast Braking System for Induction Motor. " international Journal of Engineering and innovative Technology (IJEIT), vol. 1,2012.

[7] H. Abu-Rub, A. Iqbal, and 1. Guzinski, "Direct Torque Control of AC Machines," in High Performance Control of AC Drives with MATLABISimulink Models, John Wiley & Sons, Ltd, 2012, pp. 171-254.

[8] H. Abu-Rub, A. Iqbal, and 1. Guzinski, "Pulse Width Modulation of Power Electronic DC-AC Converter," in High Performance Control of AC Drives with MATLABISimulink Models, John Wiley & Sons, Ltd, 2012, pp. 45-138.

[9] M. Zelechowski, "Space vector rnodulated-direct torque controlled (dtc-svm) inverter-fed induction motor drive. " PhD Thesis, WarsawPoland,2005.

[10] J. Rodriguez, 1. Pontt, C. Silva, R. Huerta, and H. Miranda, "Simple direct torque control of induction machine using space vector modulation," Electronics Letters, vol. 40, no. 7, pp. 412-413, Apr. 2004.

[11] C. H. Bae, M. S. Han, Y. K. Kim, C. Y. Choi, and S. 1. Jang, "Simulation Study of Regenerative Inverter for DC Traction Substation," in Proceedings of the Eighth international Conference on Electrical Machines and Systems, 2005. lCEMS 2005, 2005, vol. 2, pp. 1452-1456.