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Direct Torque and Flux Control for Speed Regulator of an Induction Motor Drive Using Combined Pi and Fuzzy Logic Controller

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Abstract:
Electric Drive is a set of devices used to convert Electrical Energy to Mechanical Energy and to regulate the converted energy flux according to a specific law. The wide spread Industrial use of Electric Drives starts from the discovery of Rotating Magnetic Field and construction of three phase Induction Motor. The need for simple advanced control alternatives arises in Control Process. The application of Fuzzy Logic to wide range of control applications has made possible the establishment of Intelligent Controlling in the Control Processing. The main drawback of the DTC of IMD using conventional PI controller based SR is high torque, stator flux ripples and speed of IMD is decreasing under transient and steady state operating conditions. This drawback was eliminated using the FLC based SR loop. The FLC based SR control scheme combines the benefits of DTC technique along with FLC technique. The work of this project is to study, evaluate and compare the technique of the conventional DTC and DTC-FLC applied to the induction machine through simulation.

Keywords:
Conventional PI controller, Direct Torque Control (DTC), Fuzzy Logic Control (FLC), Induction Motor Drives (IMD), Space Vector Modulation (SVM).

I. INTRODUCTION:

A typical drive system is assembled with a Electric Motor (may be several) and a sophisticated control system that controls the rotation of the motor shaft. Now a day, this control can be done easily with the help of software. So, the controlling becomes more and more accurate and this concept of drive also provides the ease of use. Rotational mechanical loads which can operate with wide range of speeds are often called as variable speed drives or adjustable speed drives. Prime movers are needed in a drive system to result in motion or movement [1]. The energy that is required to impart motion is derived from the sources like diesel or petrol engines, hydraulic motors and electric motors. Hence these adjustable speed drives are basically classified into three types namely, hydraulic drives, mechanical drives and electric drives. In this thesis only electric drives are considered for analysis [2]. In the FOC, the motor equations are transformed into a coordinate system that rotates in synchronism with the rotor flux vector control. 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. The main feature of DTC is simple structure and good dynamic behavior and high performance and efficiency. The new control strategies proposed to replace motor linearization and decoupling via coordinate transformation, by torque and flux hysteresis controllers [3].

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This method referred as conventional DTC. In the conventional DTC using PI based SR, there are more disadvantages, such as, variable switching frequency, high torque and flux ripple, problem during starting and low speed operating conditions, and flux and current distortion caused by stator flux vector changing with the sector position, in those most important is the speed of IMD is changing under transient state to steady state operating condition. This drawback was eliminated using fuzzy logic control speed regulator instead of conventional PI speed regulator [4].

II. INDUCTION MOTOR DRIVE CONTROL

Due to its simple, rugged and inexpensive construction and excellent operating characteristics Induction Motor has become very popular in industrial applications. As a rough estimate nearly 90 percent of the world's AC motors are polyphase Induction Motors. AC Induction Motor is the most common motor used in industries and mains powered home appliances. It is biggest industrial load, so widely used. Engineers have to know its performance, have to control as per load requirement & protecting Induction Motor also. In initial years D.C. motors were widely used in applications where high performance in variable speed was required [5].

Separately excited D.C. motors were extremely used in areas where fast torque was a must. DC motor had its disadvantage like maintenance, sparking, difficulty in commutation at high current and voltage so it is limited to low power and low speeds. After the invention of the induction motor above mention difficulties was overcome. Then after invention of power electronics components and scalar control method like Variable Frequency Drive (VFD) or Slip Frequency Control, Induction Motors were widely used again but they didn't have de-coupling facility of torque and flux. So for the de-coupling of torque and flux, vector control introduced for better performance of Induction Motor application [6]. A general classification of the variable frequency IM control methods is presented in Fig 1.

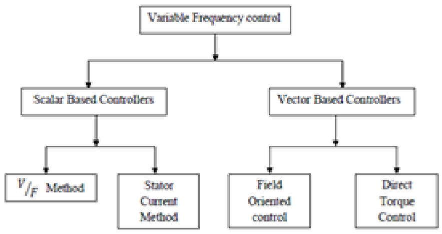

Fig:1 General Classification Of Induction Motor Control Methods

It is very important to control the speed of Induction Motors in industrial and engineering applications. Efficient control strategies are used for reducing operation cost too. Speed control techniques of Induction Motors can be broadly classified into two types – Scalar Control and Vector Control. Scalar Control involves controlling the magnitude of Voltage or Frequency of the Induction Motor, whereas the Vector Control involves not only the magnitude of Voltage or Frequency but also instantaneous positions of Voltages, Currents and Flux [7]. Vector Control mode of operation is defined as a control technique in which two equivalent control signals are produced to control Torque and Flux in decoupled manner. When three-phase Induction Motor is operated in Vector Control mode, its response improves considerably and it acts as a better substitute for the separately excited DC motor.

The field and the armature currents respectively can control the Flux and Torque, independently in the case of DC motors. It is because of this inherent decoupling between the field Flux and the armature current, one is able to achieve very good torque dynamics from DC machines. Therefore, achieving good torque dynamics in AC machines is not easy. Vector control is the most popular control technique of AC induction motors. In special reference frames, the expression for the electromagnetic torque of the smooth-air-gap machine is similar to the expression for the torque of the separately excited DC machine [8]. In the case of induction machines, the control is usually performed in the reference frame (d-q) attached to the rotor flux space vector.

That's why the implementation of vector control requires information on the modulus and the space angle (position) of the rotor flux space vector. The stator currents of the induction machine are separated into flux- and torque producing components by utilizing transformation to the d-q coordinate system. The block diagram of Vector Control is shown in Fig 2.

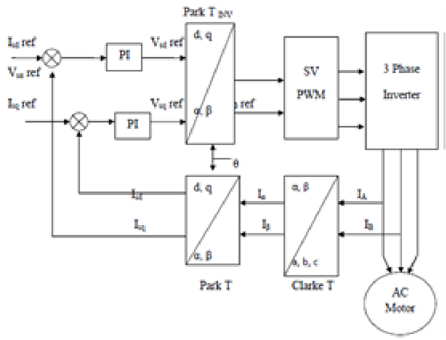

Fig:2 Block Diagram of FOC

In a Direct Torque Controlled (DTC) Induction Motor Drive supplied by a voltage source inverter, it is possible to control directly the stator flux linkage ψs and the electromagnetic torque by the selection of an optimum inverter voltage vector. The selection of the voltage vector of the voltage source inverter is made to restrict the flux and torque error within their respective flux and torque hysteresis bands and to obtain the fastest torque response and highest efficiency at every instant. DTC enables both quick torque response in the transient operation and reduction of the harmonic losses and acoustic noise [9].

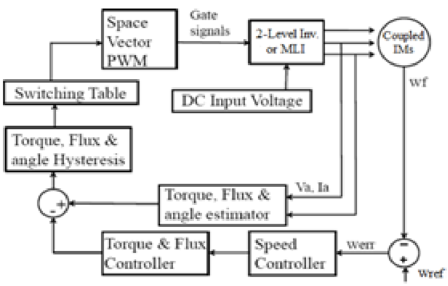

Fig:3 Block Diagram of DTC Model

A FLC converts a linguistic control strategy into an automatic control strategy, and fuzzy rules are constructed by expert knowledge or experience database. Firstly, the input speed and the change in error speed have been placed of the speed to be the input variables of the FLC. Then the output variable of the FLC is presented by the control reference torque T. To convert these numerical variables into linguistic variables, the following five fuzzy levels or sets are chosen as: NL (negative large), NS (negative small), ZE (zero), PS (positive small), and PL (positive large) as shown in Fig.4.

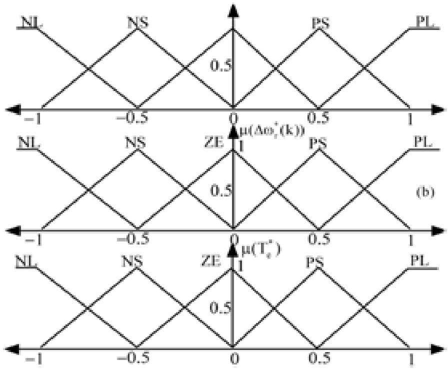

Fig:4 The fuzzy membership functions of input variables (a) speed error, (b) change in speed error, and (c) output variable.

The fuzzy logic control is one of the controllers in the artificial intelligence techniques. Fig.5 shows the schematic model of the DTC of IMD and FLC based SR. In paper the Mamdani type FLC is using. In the DTC of IMD using conventional PI controller based SR are requires the precise mathematical model of the system and appropriate gain values of PI controller to achieve high performance drive. Therefore, unexpected change in load conditions would produce overshoot, oscillation of the IMD speed, long settling time, high torque ripple, and high stator flux ripples. To overcome this problem, a fuzzy control rule look-up table is designed from the performance of speed response of the DTC of IMD [10]. According to the speed error and change in speed error, the proportional gain values are adjusted on-line.

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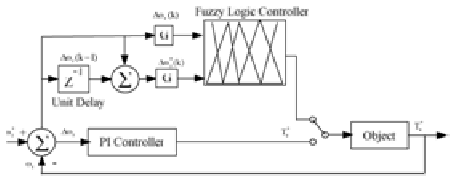

Fig:5 The structure of Fuzzy logic control based speed regulator.

III. SIMULATION RESULTS

Fig.6 shows the simulink diagram for simulation of Direct Torque Control of Induction Motor. Main subsystems are the voltage conversion(three phase to two transformation), torque & flux estimator and speed regulator. The simulink diagram is shown in Fig 6 is constructed according to the block diagram of DTC of Induction Motor. The subsystems are modeled with respect to the equations and respective theory. The estimated values of the flux and Torque is calculated from the dq parameters of voltage and currents. The reference torque is calculated from the speed error and compared with the estimated torque and the torque error is passed through torque hysteresis band in order to check the error is within the limit or not.

In the flux hysteresis band, the estimated flux is compared with reference flux. Based on the flux, torque and theta, the voltage vector is selected and thus the inverter output is varied to control the Induction Motor. The fuzzy logic control is one of the controllers in the artificial intelligence techniques. In the DTC of IMD using conventional PI controller based SR are requires the precise mathematical model of the system and appropriate gain values of PI controller to achieve high performance drive. Therefore, unexpected change in load conditions would produce overshoot, oscillation of the IMD speed, long settling time, high torque ripple, and high stator flux ripples. To overcome this problem, a fuzzy control rule look-up table is designed from the performance of speed response of the DTC of IMD. According to the speed error and change in speed error, the proportional gain values are adjusted on-line.

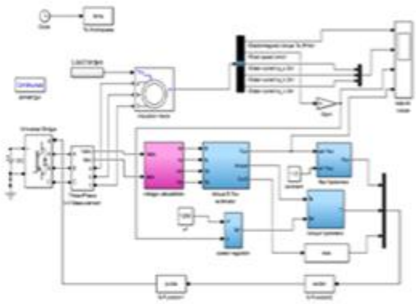

Fig:6 Simulink Model of DTC of Induction Motor

The simulation of Direct Torque Control of induction motor is done by using MATLAB-SIMULINK.

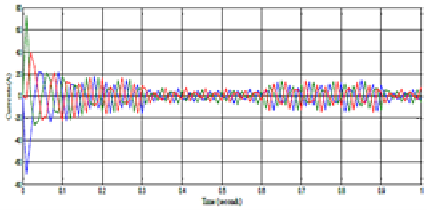

Fig:7 Stator Currents of IM Using Conventional DTC

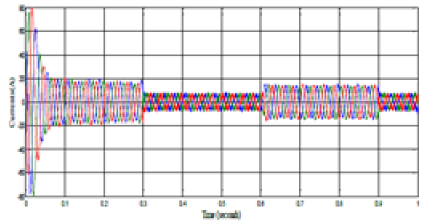

Fig:8 Stator Currents of IM Using DTC -FLC

The above Figs 7 and 8 shows the currents waveforms using both conventional and fuzzy logic control of IM. At the time of start, high starting ripples are observed in conventional DTC where as the ripples are low in fuzzy logic DTC. A load is applied (at t=0.6) the current is increased in both the control schemes but during loading conditions also the little higher ripples are observed in conventional DTC.

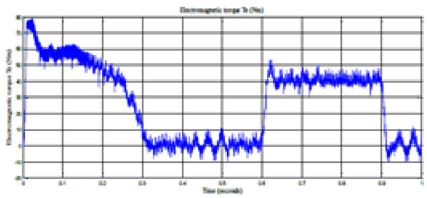

Fig:9 Torque of IM Using Conventional DTC

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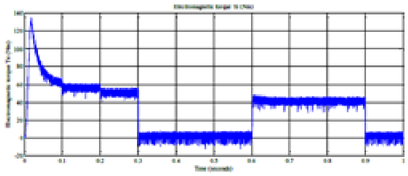

Fig:10 Torque of IM Using DTC -FLC

In Figs 9 and 10 shows the torque waveform of IM using conventional DTC and fuzzy control of IM respectively. In Fig, the starting ripple content is higher than the fuzzy control as shown. During loading (t= 0.6 and load is 40 N-m) the fuzzy control produces lower ripple content. By using FLC, high quality of torque is achieved.

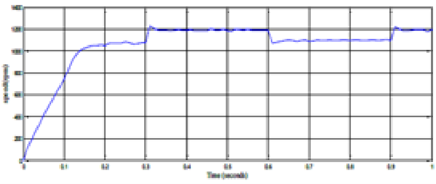

Fig:11 Speed of IM Using Conventional DTC

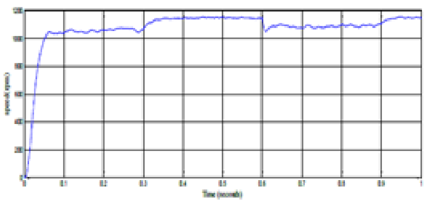

Fig:12 Speed of IM Using DTC -FLC

The IM attained its reference speed at t = 0.3, but the speed ripples in FLC is lower when compared to conventional control. At loading (t = 0.6) the speed is decreased (torque is increased) to drive the load in both the control schemes. After removal of load (t = 0.8), a little ripples are observed in conventional control of IM where as the constant speed is obtained in FLC of IM. At the starting the higher ripples are obtained. The following table-1 shows the comparision of Vector Controllers of Induction Motor. Almost in all aspects the DTC of Induction Motor is superior when compared to Scalar Control and as well as Field oriented Control.

Table-1 Comparision of Vector Controllers

Comparison property	FOC	DTC
Dynamic response to torque	Fast	Very fast
Coordinates reference frame	α, β (rotor)	d-q (stator)
Controlled variables	Rotor flux, torque current iq& rotor flux current id vector component	Torque & stator flux
Control tuning loops	Speed (PID control), rotor flux control (PI), id and iq current controls (PI)	Speed (PID control)
Current control	Required	Not required

Table-2 Comparision between DTC-PI and DTC FLC

Parameter	DTC-PI	DTC –FLC
Control method	Conventional	Artificial Intelligence
Ripple content	High	Low when compared DTC-PI
Gian values (PI values)	Fixed	Adopted Online
Current ripples	High	Reduced
Speed	Low Ripples observed after steady state also.	No ripples after steady state

The flux and speed graphs in both the methods, the waveforms are close to each other. But the ripples in torque and currents using conventional DTC- PI is higher that of the DTC–FLC

IV. CONCLUSION:

The work presented in it is a study of different control strategies of Induction Motor drive based on their simulation results. Scalar control technique is compared with vector control scheme. In vector control, the DTC is superior for the torque ripples reduction. For evaluation of implementation of drive, different responses of drive are presented. To verify the proposed converter drive system MATLAB has been chosen in the work due to its versatility. Simulation results are presented for operating conditions. All the conclusions drawn are obtained by analyzing the simulation done in MATLAB.

REFERENCES:

[1] Abdesselam Chikhi1, Mohamed Djarallah "Comparative Study Of Field-Oriented Control and Direct-Torque Control of Induction Motors using An Adaptive Flux Observer" in Serbian journal of Electrical Engineering vol.7, no.1, may 2010.

[2] AhmetGani , Mustafa Sekkeli , "Speed Control of Direct Torque Controlled Induction Motor By using

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

PI, and Fuzzy Logic Controller" in Intelligent Systemsand Applications in Engineering (IJISAE).
[3] Boldeea, I; "Nasar, S.A. "Vector Control of AC Drives "CRC Press Inc,1992.

[4] Bose, B. K. "Power Electronics and AC Drives" Prentice Hall, 1986.

[5] F. Blaschke, "The principle of field-orientation as applied to the Transvector closed loop control system for rotating-field machines", in Siemens Reviev 34, 972, pp.217- 220.

[6] Gaddam Mallesham, Member, IEEE, K.B. Venkata Ramana, "Improvement in Dynamic Response of Electrical Machines with PID and Fuzzy Logic Based Controllers" in Proceedings of the World Congress on Engineering and Computer Science 2007 oct 24-26 2007.

[7] Implementation of a Direct Torque Control Algorithm for Induction Motor Based on Discrete Space Vector Modulation," IEEE Trans On Power Electronics,15 (4) 769- 776 July 200.

[8] K. B. Mohanty, " A direct torque controlled induction motor with variable hysteresis band" in the Conf.on Compo Modeling and Simulation, UKSim2009.

[9] Leonhard, W. "Control of Electrical Drives" Springler-Verlag, 1990.

[10] Ludtke, I.; Jayne M.G. " A comparative study of high performance speed control strategies for voltage sourced PWM inverter fed induction motor drives", Seventh International Conference on Electrical Machines and Drives, 11-13 September 1995, University of Durham, UK.

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