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Comparative Analysis of Three Level Inverter Fed Induction Motor Drive with and Without DTC Technique

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ABSTRACT: In this paper, the torque and speed ripple of an Induction Motor (IM) fed by a three level Neutral Point clamped Inverter (NPC) is compared with and without Direct Torque Control (DTC). The main disadvantage of conventional DTC is variable switching frequency and fast sampling time because of hysteresis based control loops. To eliminate this disadvantage, a basic control technique called direct torque control with space vector modulation has been developed here. The modified DTC uses the PI controllers and a space vector modulator (SVM) technique instead of hysteresis controller. By this method fixed switching frequency is achieved which reduces the switching losses as well as torque and speed ripple.

KEYWORDS: Induction Motor, Direct Torque Control, Multi level Inverter, Space vector Modulation.

I. INTRODUCTION

Now a days most of the electric drives used in our industry are adjustable speed drives. An Induction Motor is the most modest electrical machine from constructional point of view because of robustness, cheapness, high speed operation and less maintenance requirement.[1] Induction Machine always run at a speed lower than synchronous speed. For industrial sectors involving IM drives, speed and torque control is a critical issue especially in dynamic condition. Induction Motor can be controlled through scalar and vector control techniques. In this project a vector control technique called Direct Torque Control is done. The main advantages of the DTC technique are absence of co-ordinate transform, absence of voltage modulator block, minimal torque response time[2]. But DTC technique has many disadvantages also. That is, it require fast sampling time and variable switching frequency, because of hysteresis based control loop. In order to eliminate these disadvantages, DTC with space vector modulation has been developed here. Torque and current ripple are occurred in the conventional DTC. Reason of undesired torque and current ripple is less number of voltage vectors applied to the motor controlled by the conventional DTC technique [3]. SVM DTC is a technique to reduce ripple. It allows achieving fixed switching frequency, which reduces switching losses and speed and torque ripples.

Also Voltage Source Inverter topology implemented for Induction Motor is multilevel inverter. Various topologies are used for the multi-level inverters. Multi-level inverter technology is emerged as a very important alternative in the area of medium voltage high power energy control. They are widely used because of higher number of dc voltage sources, lower EMI, requirement of semiconductor power devices with less blocking voltage, lower % THD in output voltage and less stress on insulation[4]. Among this commonly used topology is flying capacitors, cascade H-bridge, neutral point clamped and dual inverter fed open ended winding induction motor structure. Here, three level neutral point clamped inverter topology is used[5].

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Paper is organized as follows. Section II describes the three level neutral point clamped inverter with space vector modulation. DTC technique is explained in section III. Section IV presents the simulations and their results. Section V presents conclusion.

II. RELATED WORK

Three Level neutral point clamped inverter

A 3 level neutral point clamped inverter is shown in fig 1. A three level neutral point clamped inverter contain 12 switching devices and two capacitors are connected in series. The point between these capacitors is the DC-voltage neutral point. Each phase leg consists of 4 series-connected switching devices and two clamping diodes.

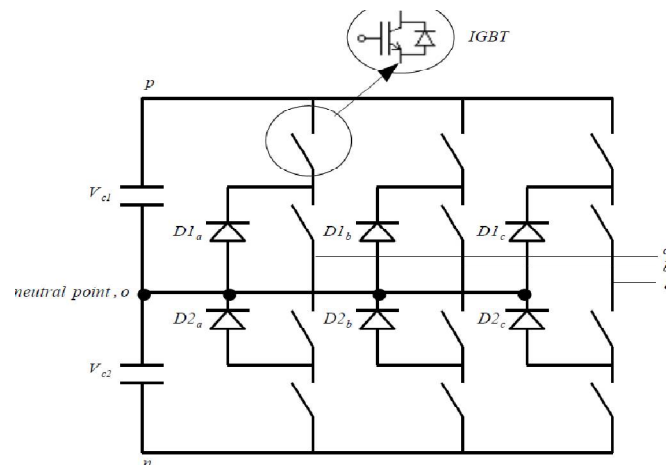


Fig 1: Three level neutral point clamped inverter

The clamping diode is to clamp the six middle switches potential to the DC-link point at zero. Specific combination of twelve switches gives the three level output voltage. The four switches in one phase leg can only be turned on two times and so be connected to the DC-link points p, o, n

Table 1 : Switching States

S_{1x}	on	off	off
S_{2x}	on	on	off
S_{3x}	off	on	on
S_{4x}	off	off	on
V_{x0}	Vdc	0	-Vdc
Switching states	P	O	N

A three level three phase inverter has 27 switching states. These states represent the connection to the different DC-link points. If there is a load connected to the output of these states the inverter will generate output phase voltage.

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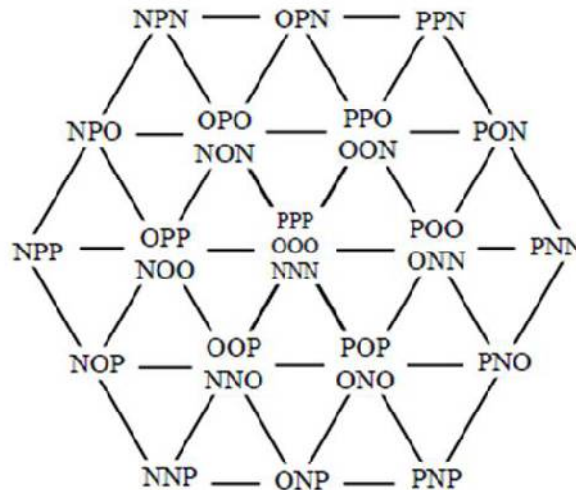


Fig 2: Vector diagram

Figure 2 shows the vector diagram of a three level neutral point clamped inverter. For a 3 level three phase inverter has 27 switching states is shown here. It generate 5 levels of output. ie, 2Vdc, Vdc, 0, -Vdc, -2Vdc.

III. PROPOSED DTC TECHNIQUE

Direct Torque Control is a method to control the utilizing torque and flux of motor. Basic DTC consists of two comparator, switching table, voltage source inverter, torque and flux estimator block and an Induction Motor.

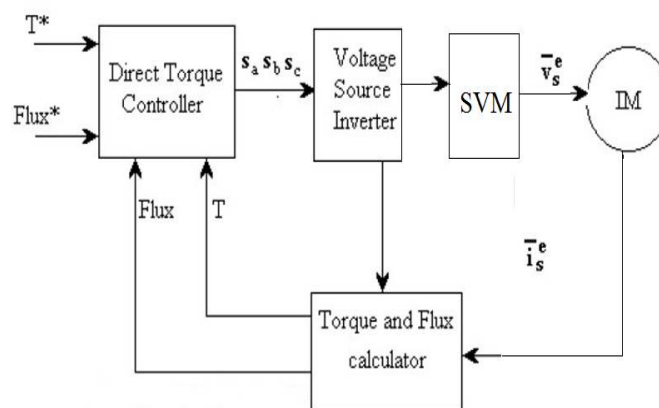


Fig 3: Block diagram of proposed system

Figure 3 shows the block diagram of the proposed system. Here, the speed from Induction Motor is sensed and fed back to the comparator circuit. These feedback speed and reference speed are compared and an error signal is generated. This

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error signal is processed with the help of PI controller. The electromagnetic torque and flux are calculated from motor inputs like stator voltage and current. The controller initiates with the direct selection of stator voltage vectors according to torque and flux error. These errors are the difference between references of torque and stator flux linkage with their actual value. Here, flux and torque estimating equations are used to determine the actual value of the flux linkage and torque. The torque and flux equations are given below:

$$V_{ds} = R_s i_{ds} + \frac{d\phi_{ds}}{dt} \dots\dots\dots 1$$

$$V_{qs} = R_s i_{qs} + \frac{d\phi_{qs}}{dt} \dots\dots\dots 2$$

$$\phi_{ds} = \int (V_{ds} - R_s i_{ds}) dt \dots\dots\dots 3$$

$$\phi_{qs} = \int (V_{qs} - R_s i_{qs}) dt \dots\dots\dots 4$$

$$\phi_s = \phi_{ds} + j\phi_{qs} \dots\dots\dots 5$$

$$T_e = \frac{3}{2} P (i_{qs} \phi_{ds} - i_{ds} \phi_{qs}) \dots\dots\dots 6$$

By using PI controllers and numeric calculations, create the voltage corresponding to dq stationary reference frame. This quantities are transformed into abc frame and is used for creating reference voltage. Torque angle is used for sector selection. The reference voltage which compensate the error is created which is used for modulating with the carrier and the switching signals are generated that is given to the inverter, then the inverter output is given to IM. Appropriate space voltage vector can be generated with SVM and fixed switching frequency can be achieved. Thus torque and speed ripple get reduced. The main features of DTC technique is decoupled control of torque and flux, current regulators and co-ordinate transformation are not required, mechanical transducers are absent, it reduces parameter sensitivity. DTC is a simple control scheme and have low computational time.

IV. EXPERIMENTAL RESULTS

The proposed system is simulated using Matlab and the results are verified. The parameters of Induction Motor drive are shown in Table 2

Table 2: Induction motor parameters

Parameters	Value
Stator resistance	0.19
Rotor resistance	0.39
Mutual inductance	4mH
No: of poles	4
Frequency	50
inertia	0.0226

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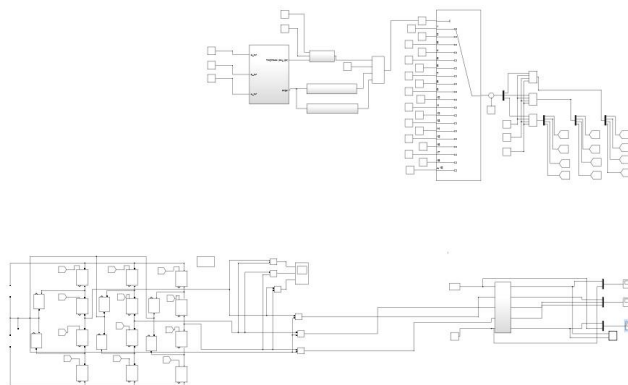
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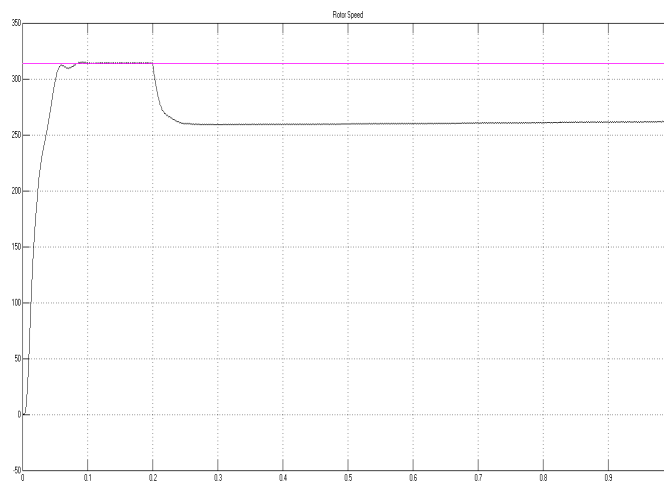
Figure 4 shows the three level inverter fed induction motor without DTC.

Fig 4(a) shows the MATLAB simulink model of three level neutral point clamped inverter fed with Induction Motor.



(a)

. The speed of Induction Motor is shown in fig 4(b). Here the speed ripple is obtained as 2% without DTC technique.



(b)

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Fig 4(c) shows the torque of an induction motor. Here the torque ripple is obtained as 34%.

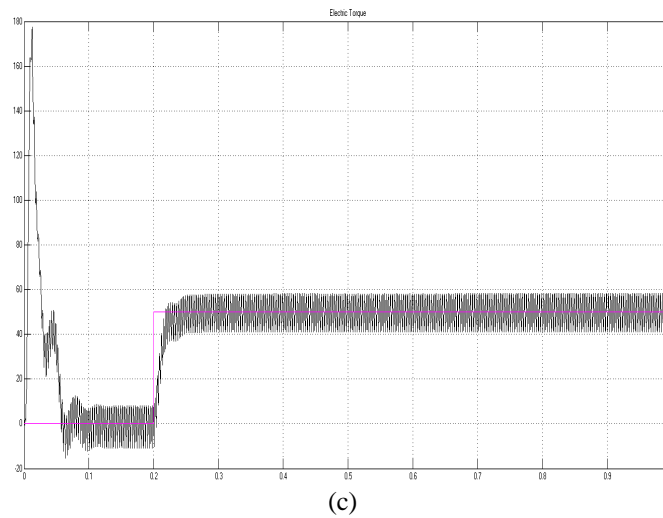
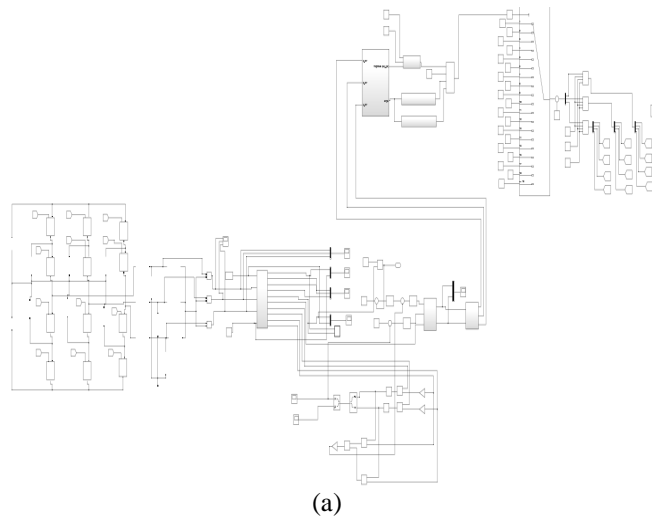


Figure 5 shows the three level inverter fed induction motor with DTC. Fig 5(a) shows the MATLAB simulink model of three level neutral point clamped inverter fed Induction Motor.



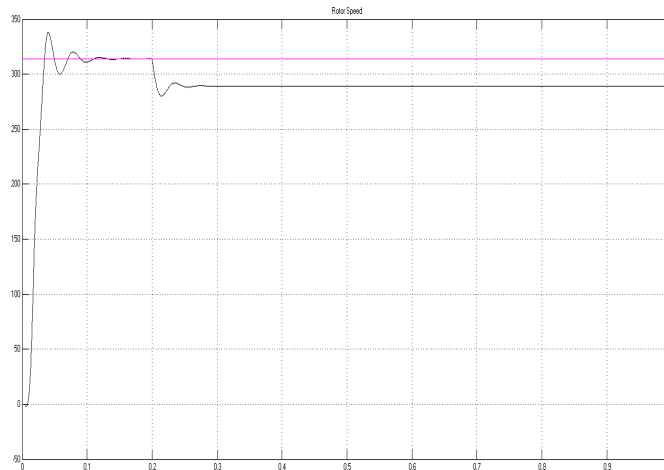
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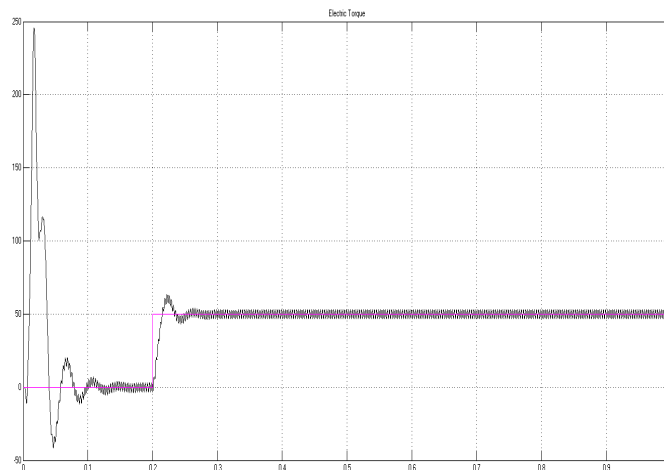
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The speed of Induction motor is shown in fig 5(b). Here the speed ripple is reduced as 0.12% by using DTC technique.



(b)

Fig 5(c) shows the torque of an induction motor. Here the torque ripple of Induction motor is reduced as 12% by using DTC technique.



(c)

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Table 3: Comparison

	3L-NPC inverter fed IM without DTC	3L-NPC inverter fed IM with DTC
Speed ripple	2%	0.12%
Torque ripple	34%	12%

V. CONCLUSION

The torque and speed ripple comparison of IM fed by 3 level neutral point clamped inverter with and without DTC have been implemented and analysed in MATLAB simulink. From this, it is obtained that the torque and speed ripple of IM is reduced with SVM-DTC.

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