Simulation of Speed Control of Induction Motor with DTC Scheme

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Abstract—This thesis work presents speed control operation of induction motor with direct torque control (DTC) method for AC Motor Drive using MATLAB / Simulink toolbox. In this method of speed control using direct torque control (DTC) Induction motor speed is controlled directly by controlling stator flux and torque form stator current measurement. By using this method we get high dynamic speed response of Induction motor. By employing SVPWM technique in proposed model for switching inverter states overcomes drawbacks like high and variable switching frequency of power electronics switches. The proposed system is examined and analyzed for dynamic response through simulation for open loop control.

Key words: Direct Torque Control (DTC), Voltage Source Inverter (VSI), Induction Motor

I. INTRODUCTION

Speed control is required in industrial process as well as at in the daily life use. Application of such variable speed drives are as pumps, fans, elevators, electrical vehicles, heating, ventilation and air-conditioning, robotics, wind generation systems, etc. DC machines are not preferred for variable speed drives, due to having disadvantages like higher cost, higher rotor inertia and maintenance problem with commutations and brushes, cannot operate in dirty and explosive environments. AC machines have no disadvantages like DC machines. So, from last some decades the DC machines are replaced by AC machine. Induction Motors (IM) are used as standard drive and recently Permanent Magnet Synchronous Motors (PMSM) are offered also. Induction Motors are often termed the "Workhorse of the Industry". This is because it is one of the most widely used motors in the world. [6]

The power requirements of motors can vary from fraction of watts to kilowatts as per application demands. Control techniques for the drive systems are changing from analog to digital mode. Improved semiconductor technology and different controlling methods can work very efficiently with Integrated Circuits (ICs) having low power consumption characteristics. The improved magnetic material, winding insulation and new design of motors are making it more useful device.

The responsible for those results are development of modern semiconductor devices. Induction Motor speed control methods are realized by using frequency converters. Converters are consisting of rectifiers, a dc link and Pulse Width Modulated VSI etc.

II. DTC CONTROL SCHEME

DTC method is a control scheme for direct torque and flux control of induction machines based on the stator flux field orientation method. With the proposed control scheme, an inverter duty cycle is directly calculated each fixed switching period based on the torque and flux errors. The inverter duty cycle can then be calculated using the PWM technique [3]. The rectifier unit is used to supply the inverter model involves combining the selection of inverter switching states with the space vector pulse width modulation (SVPWM) technique.

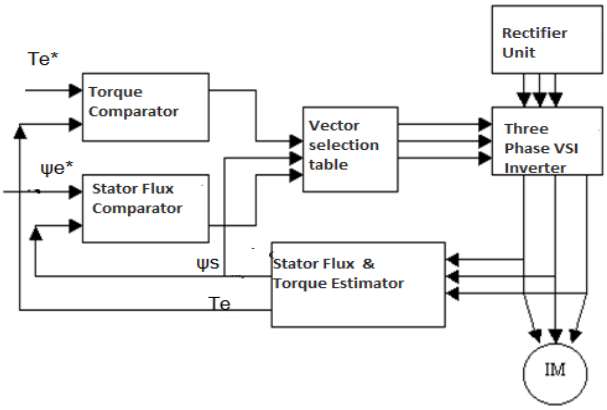

Fig. 1: Block Diagram of DTC Scheme

A. DTC Main Features are as Follows:

1) Direct control of flux and torque.
2) Indirect control of stator currents and voltages.
3) Approximately sinusoidal stator fluxes and stator currents.
4) High dynamic performance even at stand still.
5) No mechanical sensor required.

B. The main advantages of DTC are:

1) Very good seed control.
2) Absence of co-ordinate transforms
3) Absence of voltage modulator block, as well as other controllers such as PID for motor flux and torque.
4) Minimal torque response time, even better than the vector controllers.

III. THREE PHASE VOLTAGE SOURCE INVERTER

Voltage source inverter is realized using six power electronics switches like MOSFET or IGBT. Here we assume that all switches are of ideal characteristics. DC voltage Vdc is obtained using rectifier unit with filter from single or three phase utility supply. Three output voltages from inverter are given to motor phases. Figure 2 shows three phase voltage source inverter using six power switches which uses six pulse to generate three phase alternating voltage to supply three phase induction motor.

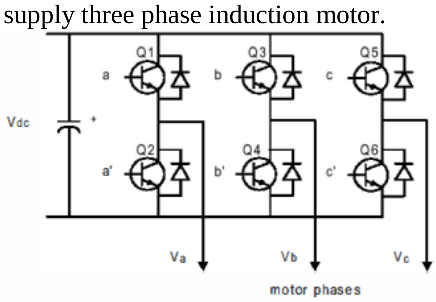

Fig. 2: Three phases VSI.

A typical voltage-source converter performs the voltage and frequency conversion in two stages: ac to dc as a first stage and dc to ac for the second stage. Although the three phase six-step inverter offers simple control and low switching loss, lower order harmonics are relatively high resulting in high distortion of the current wave (unless significant filtering is performed). On the other hand, PWM inverter offers less harmonic contents than six-step inverter.

A. Switching States

The switching state of an inverter can be represented by three variables Sa, Sb and Sc. If Sa = 1, then the lower device of the first arm of the bridge inverter is ON and the upper device is OFF. If Sa = 0, then the lower device of the first arm of the bridge inverter is OFF and the upper device is ON as shown in Figure.3.3. There are basically 2 zero switching states (000 and111) and 6 non-zero switching states (other than 000 and 111). Each of these 6 non-zero switching states has its own set of phase voltages. For example, switching state V1(1 0 0) has Van = (2V d/3), V bn= -(Vi3) and Vcn= -(V d/3). Similarly the phase voltages for each of the switching states are shown in table .

State	On devices	V_{an}	V_{bn}	V_{cn}	Space voltage vector
0	Q4Q6Q2	0	0	0	V0 (0 0 0)
1	Q1Q6Q2	$2V_d/3$	$-V_d/3$	$-V_d/3$	V1 (1 0 0)
2	Q1Q3Q2	$V_d/3$	$V_d/3$	$-2V_d/3$	V2 (1 1 0)
3	Q4Q3Q2	$-V_d/3$	$2V_d/3$	$-V_d/3$	V3 (0 1 0)
4	Q4Q3Q5	$-2V_d/3$	$V_d/3$	$V_d/3$	V4 (0 1 1)
5	Q4Q6Q5	$-V_d/3$	$-V_d/3$	$2V_d/3$	V5 (0 0 1)
6	Q1Q6Q5	$V_d/3$	$-2V_d/3$	$V_d/3$	V6 (1 0 1)
7	Q1Q3Q5	0	0	0	V7 (1 1 1)

Table 1: Inverter Switching States

The six active or non-zero vectors (V1, V 2, V 3, V 4, V 5 and V6) have a magnitude of 2Vd/3 and are 1[/3 angle apart and describe a hexagon boundary. The two zero vectors (Vo and V7) are at the origin. The voltage space vectors corresponding to each of the eight switching states are shown in figure.

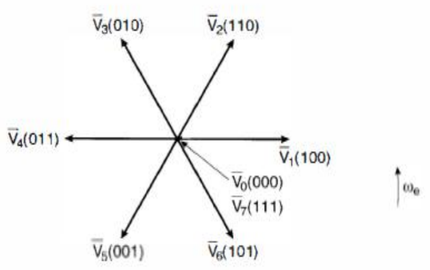

Fig. 3: position of stator space voltage vector for each switching state

IV. PWM TECHNIQUE

In many industrial applications, to control of the output voltage of inverters is often necessary with varying the DC input voltage. With the help of the PWM techniques we can control the output voltage of the inverter and vary the gain of inverter. The amplitude of the ac voltage wave form are controlled by controlling duty cycle of power electronics switches.

There are number of PWM techniques are available to control the inverter output voltage which are like:

- Single pulse width modulation
- Sinusoidal pulse PWM
- Carrier based PWM
- Space Vector PWM

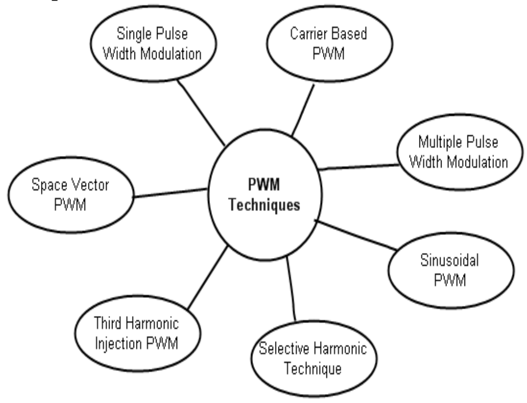

Fig. 4: PWM technique.

V. SPACE VECTOR PULSE WIDTH MODULATION

The basic idea of the SVPWM is bought from the operation of the induction motor. Traditionally in the induction motor the transformation of the three phase stator current into the two phase rotor flux is the basic formation of the space vector modulation. Space vector modulation (SVM) is an algorithm for the controlling the switching operation of the inverter. The space vector modulation mostly creates the AC waveforms to operate a 3-phase AC drives at variable speed. The space vector modulation it used for the different controlling operations and for computational requirements. SVM utilize the available DC bus voltage by 15 % more than SPWM. One of the main research area for the development of high voltage and reduction of total harmonic distortion (THD) created by the rapid switching. Its Treats the sinusoidal voltage as constant amplitude vector rotating at constant frequency, it directly uses the control variable given by the control system and identifies each switching vector as a point in complex space. Sector identification and triangle determination is to calculate the switching intervals for all vectors make SVM method quite complicated.

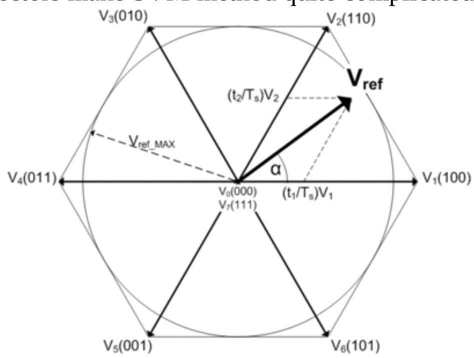

Fig. 5: Space Vector PWM for three phase two levels Inverter.

Space vector modulation is a PWM control algorithm for multi-phase AC generation, in which the reference signal is sampled regularly; after each sample, non-zero active switching vectors adjacent to the reference vector and one or more of the zero switching vectors are selected for the appropriate fraction of the sampling period in order to synthesize the reference signal as the average of the used vectors.

Power rating	5HP
Voltage	460V
Frequency	60Hz
Stator resistance	1.1158 Ohm
Stator inductance	0.005974 H
Rotor resistance	1.083 Ohm
Rotor inductance	0.005974 H
Mutual inductance	0.2037 H
Inertia	0.02 Kg.m2
Pole pair	2

Table 2: Parameters of Induction Motor

VI. SIMULATION AND RESULTS

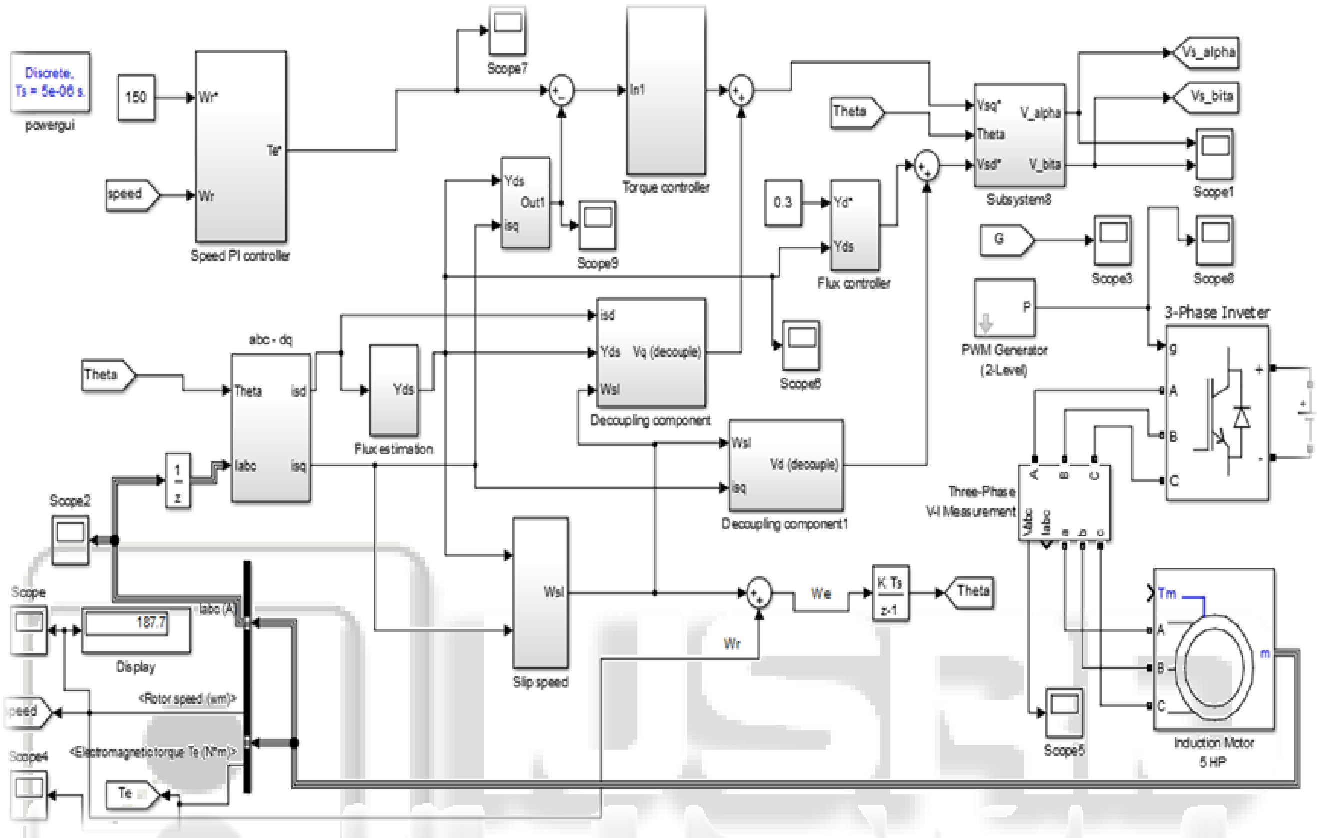

Fig.6: Simulink model for IM using DTC.

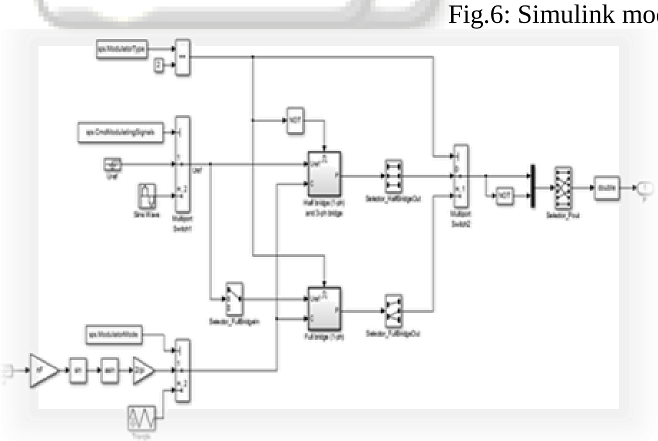

Fig.7: Simulink model for PWM generation

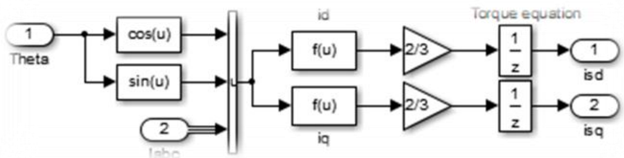

Fig. 8: Change abc component to dq component.

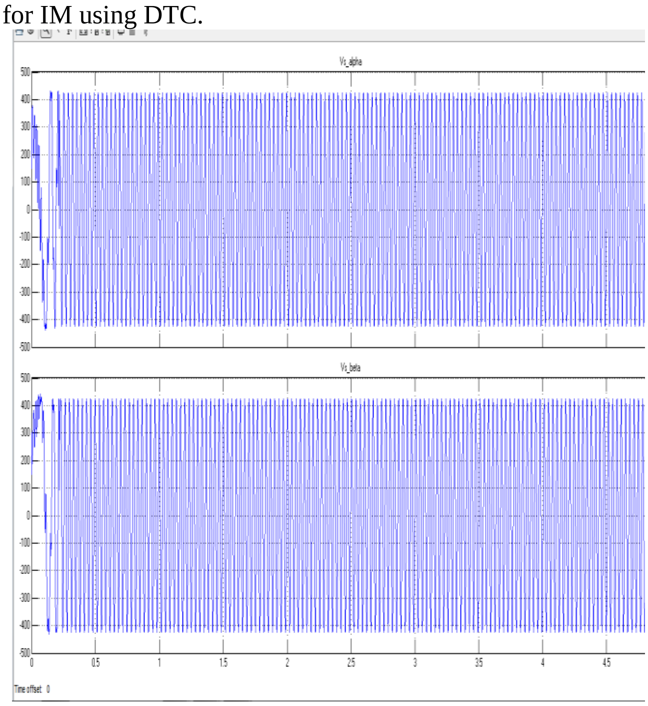

Fig. 9: Vd and Vq waveform

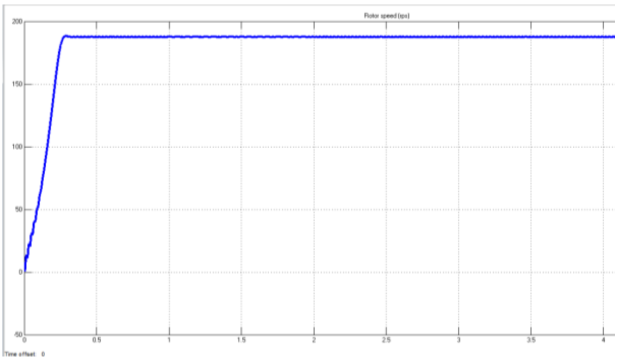

Fig.10 : Rotor Speed in rps.

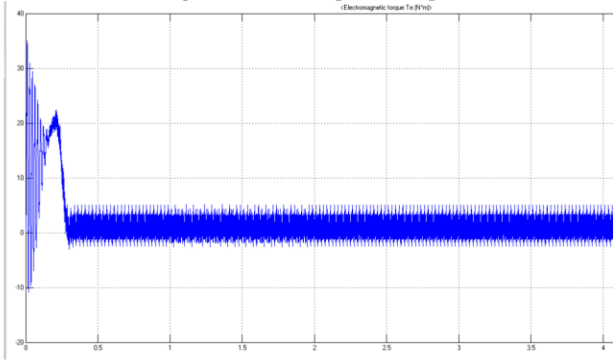

Fig. 11: Electromagnetic Torque

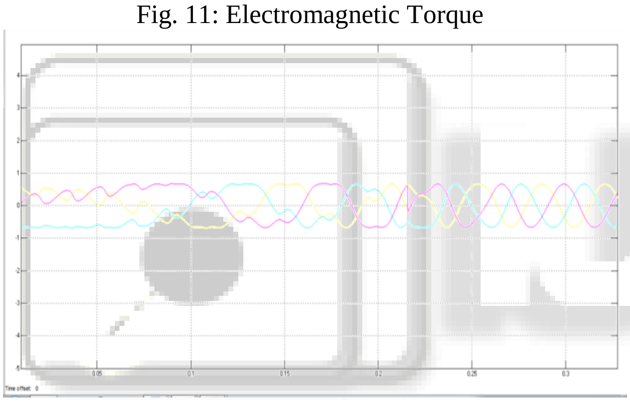

Fig. 12: Inverter gate pulse

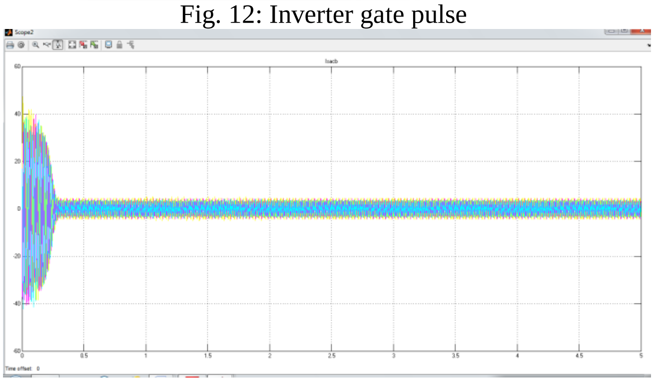

Fig. 13: Stator current waveform

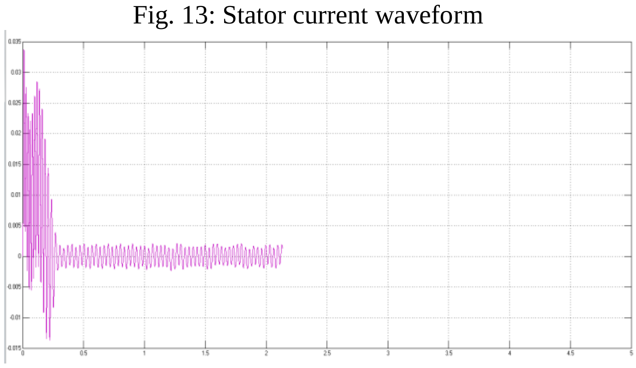

Fig. 14 Stator flux.

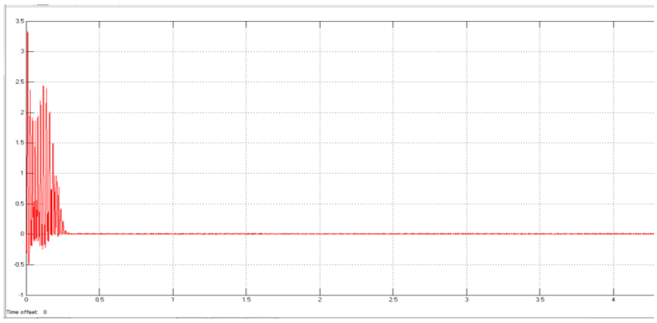

Fig. 15: Estimated Stator torque

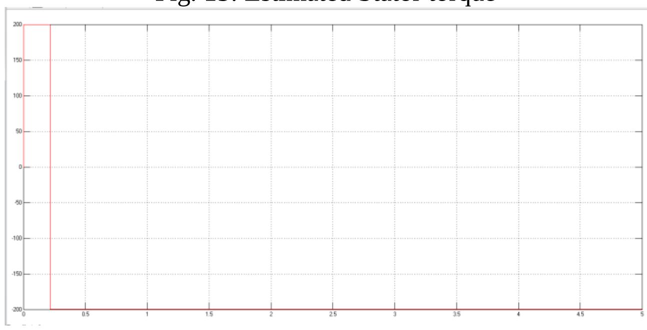

Fig. 16: Ref. torque.

VII. CONCLUSION

We can conclude from the results of that by estimation of stator flux and torque. Speed control of induction motor using DTC shows that stedy speed control done within 0.5 second and torque also attains its steady state value with in 0.5 second.. The simulation results show that combining the selection of inverter switching states in classical DTC with the SVPWM technique significantly reduces Torque, flux and current ripples. The use of Proportional integral (PI) controllers for the stator flux and the. torque regulations, limit the dynamic response.

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