Comparison and Performance Analysis of Speed Control of Induction Motor by DTC and SVM-DTC using MATLAB

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Abstract: This paper compares Conventional DTC with Space Vector PWM (SVPWM) DTC and observe the results of both then find the which method is better for the speed control of Induction motor. The simulation is carried out to control the torque and speed of 3-phase induction motorIn SVPWM instead of providing the three phase voltage we provide the revolving reference voltage vector. The study of space vector modulation technique reveals that space vector modulation technique utilizes DC bus voltage more efficiently and generates less harmonic distortion when compared with Sinusoidal PWM (SPWM) technique .The important advantages of SVPWM is that it generates the less THD as compared to the SPWM. This paper shows the simulation performance of DTC and Space Vector DTC control methods for Induction Motor by MATLAB SIMULINK and accordingly results are shown.

***IndexTerms* - Direct Torque control , Switching table, Hysteresis comparator, Induction motor, Inverter, SVPWM**

1.INTRODUCTION

Commonly used voltage source inverter is most preferable for controlling the speed of the motor because it has property of variable frequency and variable voltage. This paper describes Speed control of Induction motor by Direct torque control method and by SVM-DTC . Two types of controlling method are exist which are Field Oriented Control (FOC) and Direct Torque Control (DTC). But we are using the Direct Torque Control method for control Induction motor.FOC is not used for controlling purpose because it does not have better features than Direct Torque Control method (DTC) .

DTC has most important advantages that it controls the both primary flux and developed torque of Induction Motor simultaneously. The operation of DTC is based on the switching table. The estimated flux and torque are compared with reference values at hysteresis comparator and given to switching table .According to that voltage vector is selected and applied to inverter

In Most of the industries the Induction Motor is preferable due to its advantages. The induction motor are widely used as speed control drive in industries , commercial and domestic applications. In DTC method ,by Controlling the torque and flux quantity speed of the Induction Motor is controlled. The basic DTC scheme consists of two comparators having different features, switching table, Voltage Source Inverter (VSI), flux and torque estimation block and IM. The Hysteresis comparator consist of both Two level flux and Three level torque. When stator flux crosses its limit band ,inverter switching states changes directly to get flux within its band limit. The main advantage of DTC is directly control the stator flux and torque by appropriately selecting the inverter state.

2.DIRECT TORQUE CONTROL

Following Fig.1 shows the basic Direct Torque Control scheme for speed control Induction motor. DTC is consist of the Switching table , Hysteresis comparator and flux-Torque estimator. Overall operation of DTC is depends on sub systems which are mentioned below,

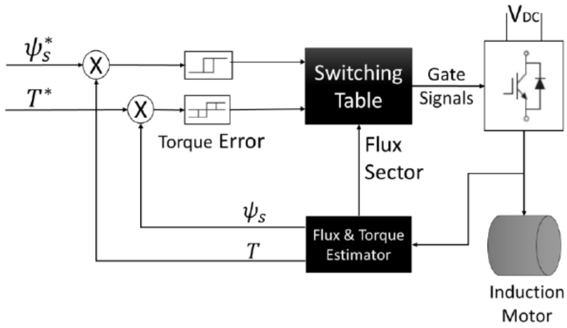

Fig.1

The Hysteresis comparator consisting of both two level flux and three level torque parameter as shown in Fig.2.

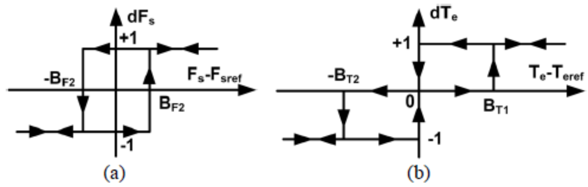

Fig.2

By taking Feedback from the motor we are estimated or calculated the value of of flux and torque. After that, this calculated value and actual or set value are to be compared at hysteresis comparator. Output of the hysteresis comparator is in digital form. According to this value as well as position of flux , switching table decided which vector is to be applied to the inverter. For this vector selection following table are provided.

Flux Error	Torque Error	Sector I	Sector II	Sector III	Sector IV	Sector V	Sector VI
1	1	V2	V3	V4	V5	V6	V1
	0	V7	V0	V7	V0	V7	V0
	-1	V6	V1	V2	V3	V4	V5
0	1	V3	V4	V5	V6	V1	V2
	0	V0	V7	V0	V7	V0	V7
	-1	V5	V6	V1	V2	V3	V4

Table 1

3. SPACE VECTOR MODULATION

Space vector modulation is one of the type of Pulse Width Modulation .It is more important technique to generates the sine wave and also supply the higher voltages to the motor with Low Total Harmonic Distortion. Block diagram of Space Vector Modulation DTC as shown below,

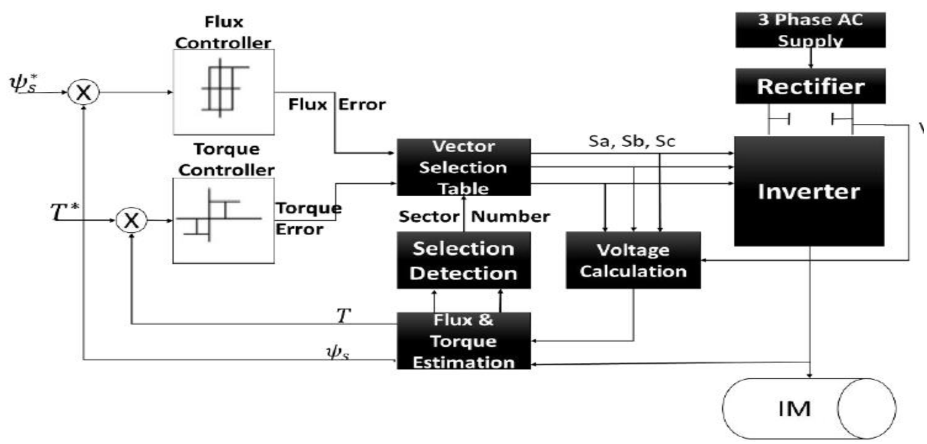

Fig.3

The Concept of the Space Vector is derived from the rotating magnetic field of Induction motor. In this Modulation technique ,we required to transform into Two phase equivalent quantity from Three phase quantity either in Synchronous frame or Stationary Frame. From these Two phase component that is Vd and Vq we found the magnitude of reference vector and used for the modulating the inverter output. The Magnitude of Reference of vector can be calculated as follows,

$$Vs = Vd + j\,Vq \qquad \text{... Eq.1}$$

The output of inverter is in three phase voltage. For calculating the torque and flux required to convert three phase to two phase axis. The following matrix are used to convert into two phase axis,

$$\begin{bmatrix} V_d \\ V_q \end{bmatrix} = \frac{2}{3} \begin{bmatrix} 1 & \frac{-1}{2} & \frac{-1}{2} \\ 0 & \frac{\sqrt{3}}{2} & \frac{-\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} V_{an} \\ V_{bn} \\ V_{cn} \end{bmatrix} \quad \text{... Eq.2}$$

SOFTWARE IMPLEMENTATION OF SVPWM

Space vector PWM can be implemented by the following steps:
Step-1: DetermineVd, Vq, V_{ref}, and angle (α)
Step-2: Determine the time duration T_0, T_1, T_2
Step-3: Determine the switching time of each transistor (S1 to S6)

Follwing some important formula concern with Space Vector PWM implementation,

Vref is nothing but the magnitude whose related to the Vd and Vq,

$$\overline{V}_{ref} = \sqrt{V_d^{\ 2} + V_q^{\ 2}} \quad \text{... Eq.3}$$

α is an angle which indicate the reference voltage vector in which sector they located,

$$\alpha = \tan^{-1}\left(\frac{V_q}{V_d}\right) \quad \text{... Eq.4}$$

Total time period ,

$$T_s = T_1 + T_2 + T_0 \quad \text{... Eq.5}$$

$\overline{V}_{ref}$ can write in real and imaginary form which shown below,

$$\left(\overline{V}_d + j\overline{V}_q\right) * T_s = V_1T_1 + V_2T_2 \quad \text{... Eq.6}$$

Switching time duration in any sector,

$$T_1 = \frac{3T_s|V_{ref}|}{V_{dc}} * \left(\sin\frac{n}{3}\pi\cos\alpha - \cos\frac{n}{3}\pi\sin\alpha\right) \quad \text{... Eq.7}$$

$$T_2 = \frac{3T_s|V_{ref}|}{V_{dc}} * \left(-\cos\alpha\, \sin\frac{n-1}{3}\pi + \sin\alpha \cos\frac{n-1}{3}\pi\right) \quad \text{... Eq.8}$$

4. RESULTS AND DISCUSSION
Simulation results are given below for Conventional DTC and Space Vector DTC ,
For DTC-
In DTC, We have to set the different load torque 0 to 20 Nm and observe the speed and torque simultaneously. So, for 0 Nm load torque speed will reach steady state point within 0.1335 sec , speed 1499 rpm . Same result observe for SVDTC,

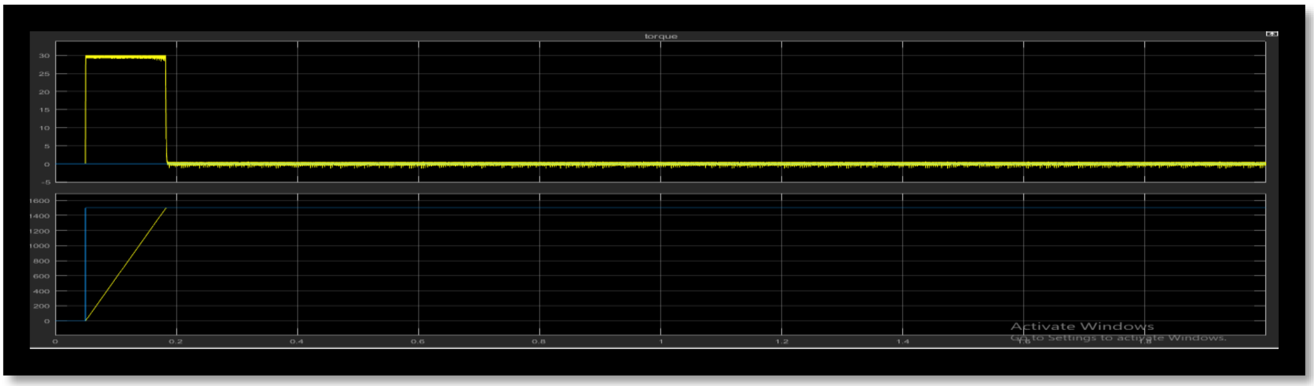

Fig.4(a)Speed and Torque

In DTC, We have to set 20 Nm load torque , speed will reach steady state point within 0.1333 sec , speed 1494rpm and Speed regulation 0.33%.

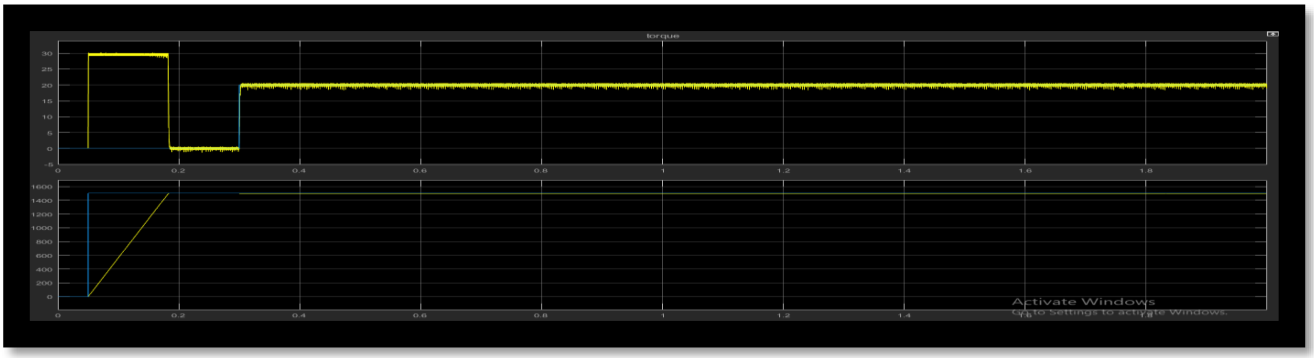

Fig.4(b) Speed and Torque

For SVDTC-

For 0 Nm load torque speed will reach steady state point within 0.1190 sec , speed 1499 rpm calculated from below graph

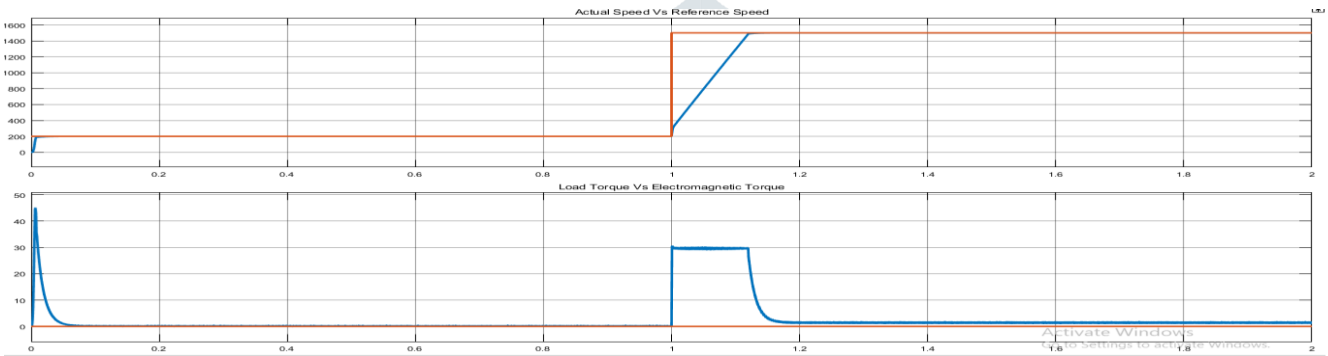

Fig.4(c) Speed and Torque

For 20 Nm load torque speed will reach steady state point within 0.560 sec , speed 1490 rpm and Speed regulation 0.15%

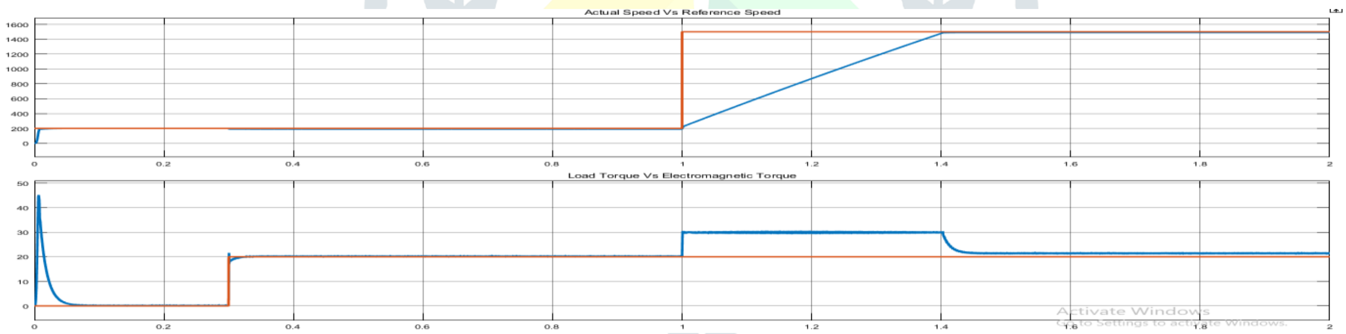

Fig.4(d) Speed and Torque

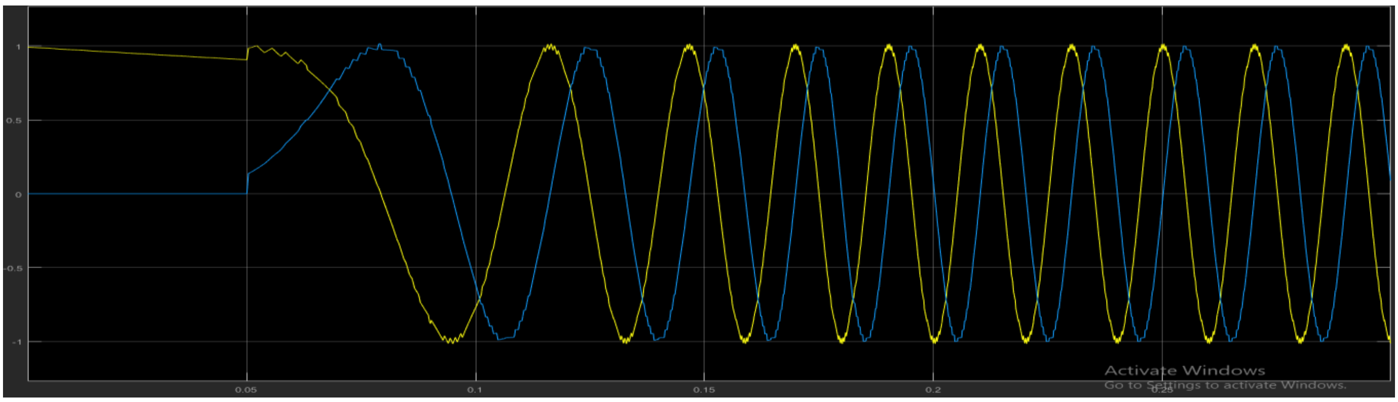

Fig.4(e)Stator d-q Flux For DTC

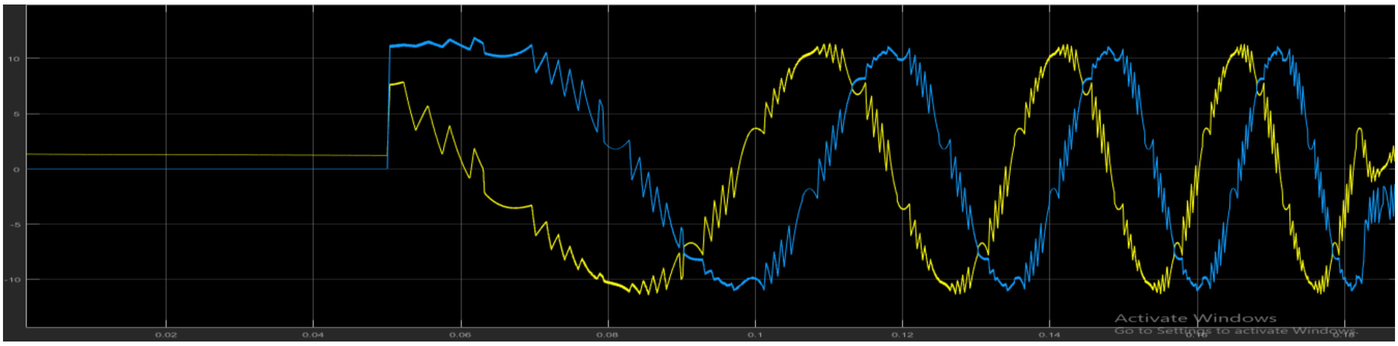

Fig.4(f) Stator Current For DTC

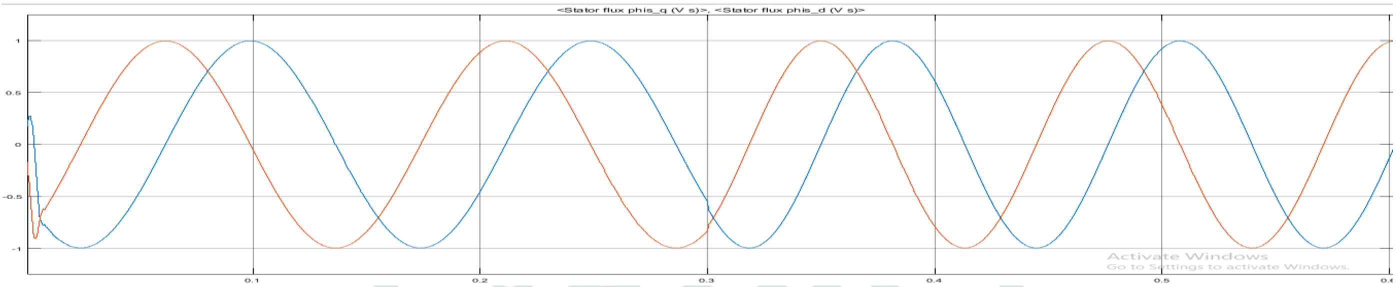

Fig.4(g) Stator d-q Flux For SV-DTC

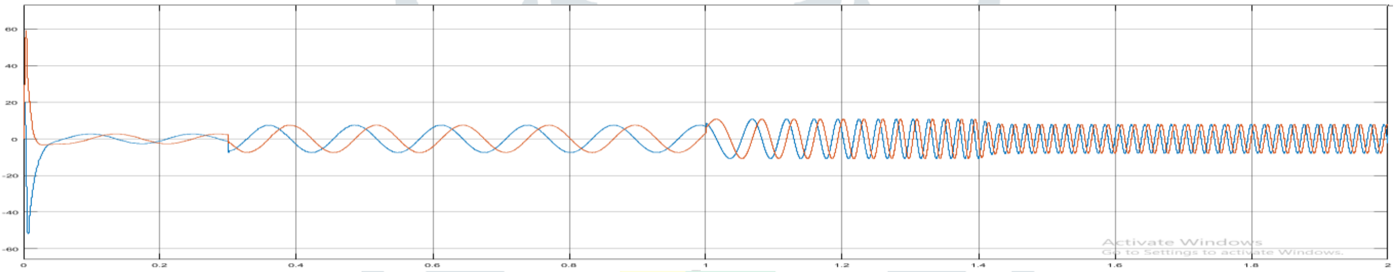

Fig.4(h) Stator Current For SV-DTC

4.1 Table for Result Calculation

4.1.1. For DTC

Load Torque(Nm)	Speed (rpm)	Speed Regulation (%)	Dynamic Response (sec)	Transient Response (sec)
0	1499	-	-	0.1335
5	1498	0.66	0.0025	0.1334
10	1496	0.50	0.0040	0.1333
20	1494	0.33	0.0045	0.1333

4.1.2.For SV-DTC

Load Torque(Nm)	Speed (rpm)	Speed Regulation (%)	Dynamic Response (sec)	Transient Response (sec)
0	1499	-	-	0.119
5	1495	0.13	0.001	0.146
10	1493	0.14	0.002	0.204
20	1490	0.15	0.003	0.560

Fig.4(a) and Fig.4(b) shows the Speed and Torque response for DTC for different load torque as well as Fig.4(c)&(d) shows the speed and Torque for SV-DTC for two various torque condition. From these graph we are calculating the values of transient period and Dynamic response for various load torque shown in above table. Comparing these two values from the above table it will conclude that transient response of SV-DTC is better than the DTC and Dynamic response of the DTC is better than the SV-DTC method. But our main aim is to control the Speed of Induction motor , so we judged from the speed regulation results, over all speed response of SV-DTC is better than DTC.

Fig.4(e) and (g) shows the Stator d-q Flux For DTC and SV-DTC. With DTC we get the stator flux waveform whose near to nature of sinusoidal. The waveform is purely not sinusoidal due to presence of harmonic and ripple content. We have to minimize these unwanted signal that is ripple content , the concept SV-DTC is used. With SV-DTC, output waveform is in pure sinusoidal form shown in fig.4(g). The same observation will be done with stator d-q current for both method. Overall performance is good with SV-DTC than DTC.

5.CONCLUSION-

By Comparing the both Conventional DTC and SV-DTC, SV-DTC method gives the better speed control because it will take less time for speed control than DTC. Overall Efficiency of the SV-DTC is high than the DTC. The both method are very effective , but in some case , For example rockets are used for the launching the probes and satellites , in this case rocket requirement is it will reach the destination point with high torque within fraction of sec , so in this case we have to use space Vector DTC which fulfill the requirements.

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