# DIRECT TORQUE CONTROL OF THREE PHASE INDUCTION MOTOR BY USING FOUR SWITCH INVERTER

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## ABSTRACT

Induction motor proved its importance, since its invention and has been used in industry extensively as it offers advantages e.g. robust, maintenance free and satisfactorily efficiency. With the invention in semiconductor technology and three phase inverter as this plays important role for speed control of motor driver. Traditionally 6 switch, 3 phase inverters are used extensively for controlling speed for motors. This may involves losses occurring in the six switches, and the complexity also increases for control algorithms and interface circuits for implementation PWM logic signals.

**KEYWORDS:** Torque Control, Four switch three phase inverter, six switch three phase inverter etc.

## INTRODUCTION

For last many years, researchers mainly concentrated on the development of the efficient control algorithms for high performance variable speed drives which can be used for induction motor. But problem is lies in the cost, simplicity and flexibility of the overall drive system. But researchers did not attend this variable, which is most important factors did not get that much attention. Thus, the main aim of this paper is to develop a cost effective, simple and efficient high performance IM drive.
Few applications of IM drive, where precision control is required are electric and hybrid propulsion system, reliable etc and all controlling parameters should be in specified limit. To achieve this aim A DTC strategy dedicated to FSTPI-fed IM drives has been proposed.
To develop new power converters with reduced cost and losses. Among these circuits, the three-phase voltage-source inverter (VSI) with only two inverter legs is an alternative solution. In comparison with the usual three phase VSI with three inverter legs, the main features of this converter are:

1) Reduction of conduction losses dependent on the power semiconductor devices.
2) Reduced switch and freewheeling diode count.
3) Potential for reduced price because of the reduction in number of switches.
4) Reduced number of drive circuits including supplies for those.

## DTC BASIC

Direct torque control of the motor variables by doing a proper selection of the control signals for the inverter, for fulfilling the requirement and decide what need to be corrected e.g. stator flux or toque. These things are decided on the basics of output produced by flux hysteresis controller, angular displacement of the stator flux and output of the torque hysteresis controller in the Clarke (αβ) plane.
The implemented scheme of the DTC strategy based on FSTPI-fed IM, as shown in Fig. No.1, has the same layout as the one of the basic DTC strategy

## INVERTER MODEL

The power circuit of the induction motor supplied from 4 switch 3 phase VSI is shown in fig.no.1. Basically circuit is divided into two parts first part is a front end rectifier which uses a single phase supply. Second part consists of the power circuit, which is actually three phase four switch inverter. The maximum possible peak value of the line voltages equals $V_{dc}$. In the analysis, the inverter switches are considered as ideal switches. The output voltages are depend on gating signals of the two leg switches and by the two dc link voltages $V_{dc}$. The phase voltages equations of the motor can be written as a function of the switching logic of the switches.
Fig. No. 1 shows the circuit diagram of a four switch and three phase inverter fed by a three-phase diode rectifier. The four switch three phase inverter topology consists of four switches that provide two inverter output phases: B and C. The third phase, is connected to the midpoint of the two split capacitors. The zero potential point is defined as point zero as shown in Fig. No. 1.

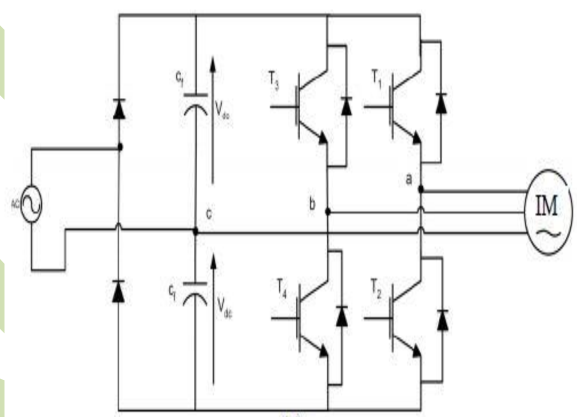


**Fig. No. 1: Power circuit of the IM fed from 4S3P voltage-source inverter.**

The phase-to-zero voltages $V_{A0}$, $V_{B0}$ and $V_{C0}$ depend on the switching states of S1, S2, S3 and S4, and two dc-link voltages ($V_{dc1}$, $V_{dc2}$). The phase-to-zero voltages are determined as follows:

$$V_{AO} = V_{dc2} \quad (1)$$

$$V_{BO} = S1\,(V_{dc1}+V_{dc2}) \quad (2)$$

$$V_{CO} = S1\,(V_{dc1}+V_{dc2}) \quad (3)$$

Where, $V_{dc}$ is the total dc-link voltage. $V_{dc1}$& $V_{dc2}$ are voltages across two capacitors C1 and C2, respectively.

Switching state $S_x = 0$ when the switch $S_x$ is off and $S_x = 1$ when the switch $S_x$ is on (x=1,2).

The following equations are obtained under balanced load conditions:

$$V_{AN}+V_{BN}+V_{CN} = 0 \quad (4)$$

$$V_{A0}+ V_{B0}+V_{C0}-3V_{N0} = 0 \quad (5)$$

$$V_{N0}= \frac{VA0+VB0+VC0}{3} \quad (6)$$

From (4)-(6), the phase-to-neutral voltages $V_{AN}$, $V_{BN}$ and $V_{CN}$ are derived:

$$V_{AN} = \frac{2}{3}V_{A0} - \frac{1}{3}(V_{B0}+V_{CO}) \quad (7)$$

$$V_{BN} = \frac{2}{3} V_{B0} - \frac{1}{3}(V_{A0}+V_{CO}) \quad (8)$$

$$V_{CN} = \frac{2}{3} V_{C0} - \frac{1}{3}(V_{A0}+V_{BO}) \quad (9)$$

By solving the above equations of 7, 8, 9 using the values from 1, 2, 3 we can derive the equations:

$$V_{an} = 2/3V_{dc} [1 - S1 - S2]$$

$$V_{bn} = V_{dc}/3[ 4S1 -2S2 – 1]$$

$$V_{cn} = V_{dc}/3[ 4S1 -2S2 – 1]$$

The line and phase voltages at each switching functions for lag is given in table1.

**Table No.1. The switching function for lag**

| Switching functions | Leg A | | Leg B | |
|---|---|---|---|---|
| | T1 | T3 | T2 | T4 |
| 1 | ON | OFF | ON | OFF |
| 0 | OFF | ON | OFF | ON |

## SPACE VECTOR MODULATION

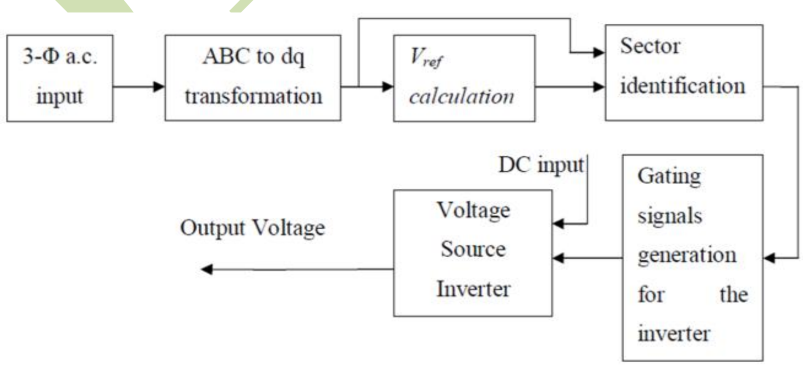


**Fig. No. 2: Block diagram of Space Vector Modulation**

Treats the sinusoidal voltage as a constant amplitude vector rotating at constant frequency. This PWM technique approximates the reference voltage $V_{ref}$ by a combination of the four switching patterns (V1 to V4) shows in table 2. Coordinate Transformation (abc reference frame to the stationary d-q frame).

**Table No.2. Voltage V1 to V4**

| | | | Phase voltage | | | line voltages | | |
|---|---|---|---|---|---|---|---|---|
| | Sa | Sb | Van | Vbn | Vcn | Vab | Vbc | Vca |
| V1 | 0 | 0 | -Vdc/3 | -Vdc/3 | -2Vdc/3 | 0 | -Vdc | Vdc |
| V2 | 1 | 0 | Vdc | -Vdc | 0 | 2Vdc | -Vdc | -Vdc |
| V3 | 1 | 1 | Vdc/3 | Vdc/3 | -2Vdc/3 | 0 | Vdc | -Vdc |
| V4 | 0 | 1 | -Vdc | Vdc | 0 | -2Vdc | Vdc | Vdc |

A three.-phase voltage vector is transformed into a vector in the stationary d-q coordinate frame which represents the spatial vector sum of the three-phase voltage. The vectors (V1 to V4) divide the plane into Four sectors (each sector: 90 degrees) $V_{erve}$ is generated by two adjacent non-zero vectors and two zero vectors.

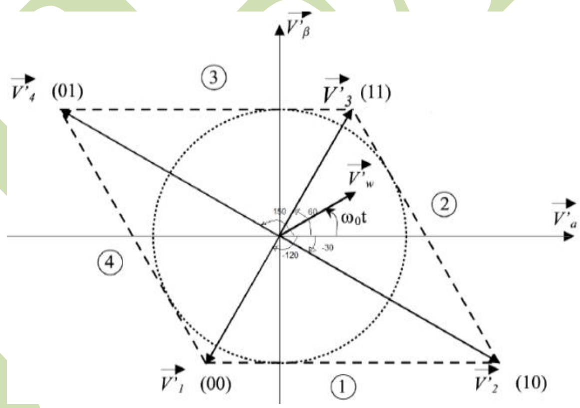


**Table 3: Magnitude & Angle for each vector**

| Vectors | Magnitude | Angle (α) |
|---|---|---|
| $V_1$ | 2/3 $V_{dc}$ | $-120^0$ |
| $V_2$ | 2/√3 $V_{dc}$ | $-30^0$ |
| $V_3$ | 2/3 $V_{dc}$ | $60^0$ |
| $V_4$ | 2/√3 $V_{dc}$ | $150^0$ |

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**Table 4: Sector & Angle range of vector.**

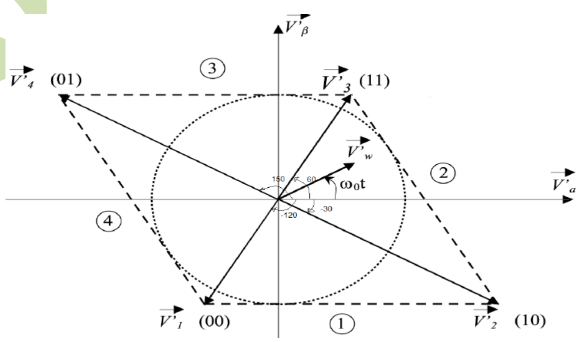
| Sector | Range of angles |
|---|---|
| 1 | $-120^0 < \alpha < -30^0$ |
| 2 | $-30^0 < \alpha < 60^0$ |
| 3 | $60^0 < \alpha < 150^0$ |
| 4 | $150^0 < \alpha < 180^0$ |

By using the combination of sector time we are calculating the switching time for 4 switches.

**Table 5: Time period of each sector.**

| SECTOR 1 | SECTOR 2 |
|---|---|
| $T_1 = \frac{3\ V_{ref} Ts \cos(\alpha)}{2V_{dc}}$ <br> $T_2 = \frac{\sqrt{3}\ V_{ref} Ts \sin \alpha}{2V_{dc}}$ <br> $T_0 = Ts-(T_1+T_2)$ | $T_2 = -\frac{\sqrt{3}\ V_{ref} Ts \sin(\alpha)}{2V_{dc}}$ <br> $T_3 = -\frac{3\ V_{ref} Ts \cos(\alpha)}{2V_{dc}}$ <br> $T_0 = Ts-(T_2+T_3)$ |
| **SECTOR 3** | **SECTOR 4** |
| $T_3 = -\frac{3\ V_{ref} Ts \cos(\alpha)}{2V_{dc}}$ <br> $T_4 = -\frac{\sqrt{3}\ V_{ref} Ts \sin(\alpha)}{2V_{dc}}$ <br> $T_0 = Ts-(T_3+T_4)$ | $T_4 = \frac{\sqrt{3}\ V_{ref} Ts \sin(\alpha)}{2V_{dc}}$ <br> $T_5 = \frac{3\ V_{ref} Ts \cos(\alpha)}{2V_{dc}}$ <br> $T_0 = Ts-(T_4+T_5)$ |

$V_{ref}$ signal lies between 3 vectors such as zero vector (corrosponding time T0 )and two adjusant vectors T1 and T2 so by using Tc=T0-(T1+T2). we are calculating total time for rotating reference vector in table 5And by using that total time we are calculating switching time for each switch in table 6,finally by using total time angle and dc source we are calculating switching time to trigger switch.



## Table 6: The switching time of each transistor (S1 to S4)

| sector | Upper switches | Lower switches |
|---|---|---|
| 1 | S1=T2+To/2<br>S3=To/2 | S2=T1+To/2<br>S4=T1+T2+To/2 |
| 2 | S1=T1+T2+To/2<br>S3=T2+To/2 | S2= To/2<br>S4=T1+To/2 |
| 3 | S1=T1+T2+To/2<br>S3=T1+To/2 | S2=T2+To/2<br>S4= To/2 |
| 4 | S1= To/2<br>S3=T1+To/2 | S2=T1+T2+To/2<br>S4=T2+To/2 |

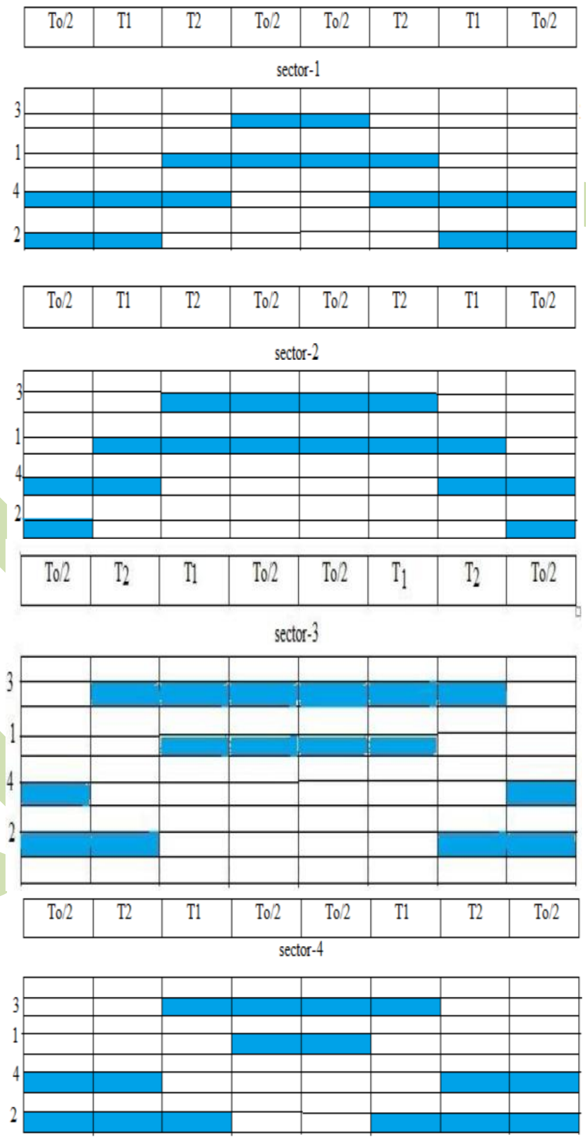
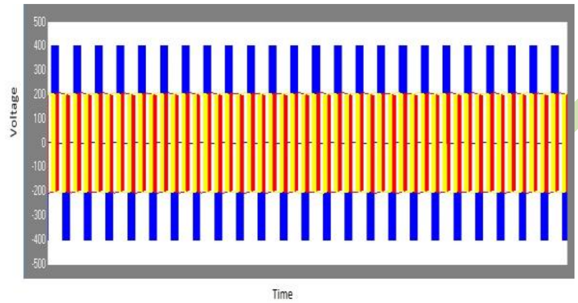



**Fig 3: Sequence Table for each sector.**

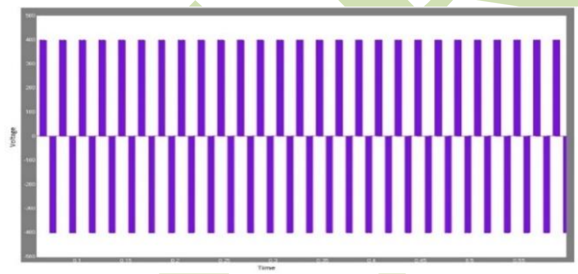
## PERFORMANCEE VOLUTION

For performance evolution, the space vector modulation are used for 0.25 Hp, 50 Hz Induction motor having four switch three phase inverter. The inverter output voltage is shown in graph 1.

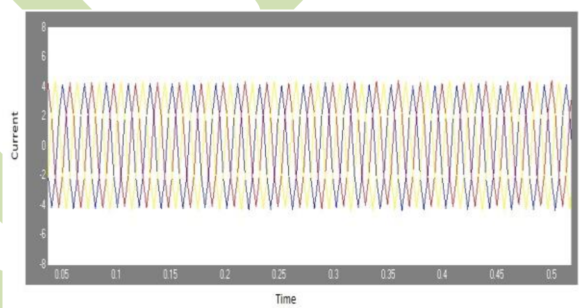



**Graph 1: Inverter three phase voltages.**

The voltage across the phase A & phase B are 400v is shown in graph 2 and The inverter current waveform shown in graph 3.

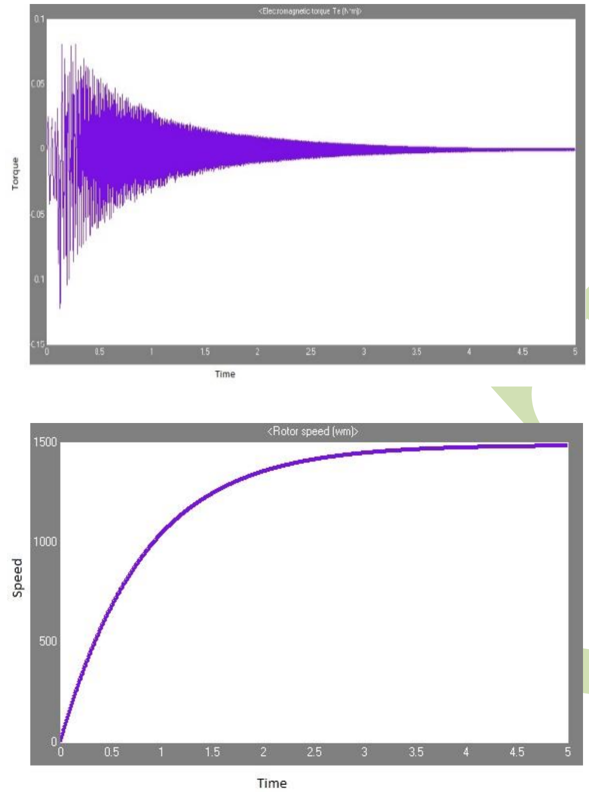


**Graph 2: Voltage across the two phase of the inverter.**




**Graph 3: Current output of four switch inverter.**

The rotor speed of three phase induction motor control by using four switch inverter, the control method are used for inverter is space vector modulation show in graph 4. Which is maintain at 1500 rpm set value. The harmonic in the speed can be reducing from space vector modulation and the torque are controlled in this method accurately.




**Graph 4 (a) &(b): Torque and Rotor speed of three phase induction motor**

A performance comparison of the 4S3P inverter fed drive with a conventional 6S3P inverter fed drive is also made in terms of total harmonic distortion (THD) of the stator current and speed response.

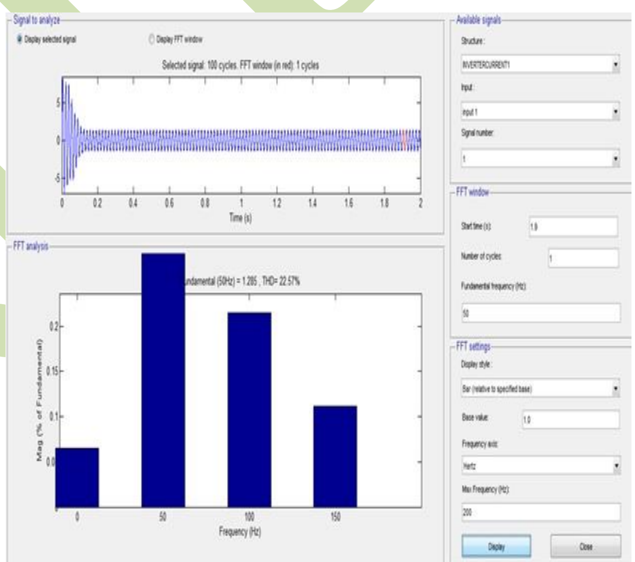



**Fig 4: THD analysis of six switch inverter**.

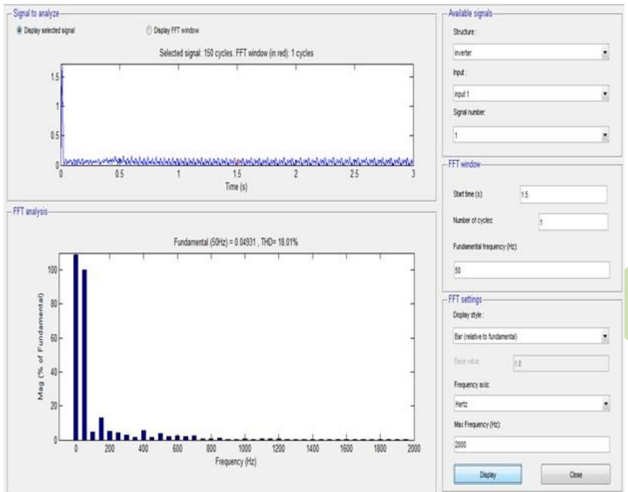



**Fig 5: THD analysis of four switch inverter.**

## CONCLUSION

Author has successfully developed simulation model of four switch inverter fed induction motor drive. The proposed control method has advantages like low cost, reduction in losses and reduces complexity of the network. Moreover easy control algorithms for implemented model as compared various available techniques. The implementation of vector control scheme is incorporated for achieving high performance. A THD, stator current and speed response, based comparison is also made between 4S3P and 6S3P and it is found that 4S3P fed induction motor is found in acceptable wherever high performance needed.

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