IMPLEMENTATION OF DIRECT TORQUE CONTROL OF INDUCTION MOTORS THROUGH SVM TECHNIQUE

1V.Kiranmayee, 2G.Naresh, 3Bhukya Ravi
1Asst.Professor, Department Of EEE, Kamala Institute of Technology and Science Singapur, Huzurabad, Karimnagar
2,3Department Of ME, Kamala Institute of Technology and Science Singapur, Huzurabad, Karimnagar

Abstract—This paper proposes design and simulation of an immediate torque control induction motor drive system based on space vector modulation and PI controller to control speed, torque and to shrink torque ripples. For controlling these the precept used here is the simultaneously decoupling of the stator flux and electromagnetic torque. Hysteresis comparators used by DTC drives undergo from high torque ripple and variable switching frequency. The proposed SVM based DTC procedure reduces torque ripples and retain DTC transient deserves reminiscent of fast torque response. The groundwork of the SVM-DTC system is the calculation of there quired space vector of voltage to compensate the errors in flux and torque and its generation utilising the SVM for each sample period. The performance of this process in this paper is established by using simulation utilizing Simulink software.

Index Terms—Direct Torque Control, Induction Motor, PI Controller, Space Vector Modulation.

I. INTRODUCTION

Almost 70% of the machines used in industries now a day are 3 phase induction motors and the research interest in induction motor (IM) drives has grown significantly over the past few years due to some of their advantages, such as induction motors are simple and rugged in construction, robust and can operate in any environmental condition. Since its introduction in 1985, the direct torque control (DTC) principle is widely using in IM drives with fast dynamics [1]. The direct torque control (DTC) based on switching table is a very simple vector control method for voltage source fed induction motor (IM). However, instead of some attractive qualities such as fast dynamic response, low sensitivity to parameter changes, lack of internal current control loops and inherently motion-sensor-less operation there exist some problems occurring with DTC, as difficulty in starting and low-speed operation, the amount of current and torque ripples, variable switching frequency and high level of noise, violence of polarity rules, as well as high sampling frequency needed for hysteresis controllers [2]. To minimize these problems this paper introduces a new direct torque and flux control based on space vector modulation (DTC-SVM) for IM drives. It uses closed-loop control for both flux and torque and speed in a similar manner as DTC, but the voltage is produced by an SVM unit. In this way, the DTC transient performance and robustness are preserved and the steady-state torque ripple is reduced. Additionally, the switching frequency is constant and totally under controlled. The classical DTC system is based on the instantaneous values and directly calculated inverter’s control signals. The control logic in DTC-SVM method is based on averaged values whereas the switching signals for the inverter are calculated by space vector modulation. This is main difference between classical DTC and DTC-SVM control system.

DTC has two main disadvantages which are switching frequency is varies according to motor speed and hysteresis band of torque and flux and second is high torque ripple are generated. For reducing the problem of varying switching frequency and torque ripple space vector modulation (SVM) technique is used. This technique is proposed by Habetler et al [6]. Now many concept of DTC of induction motor using SVM have been developed[7]-[9].

Here the analysis of DTC of three phase squirrel cage induction motor based on svpwm is carried out with simple approach. Here in this paper 6-sided hexagonal
space vector modulation is used for analysis purpose of an inverter fed IM. Inverter switching is depend on output values of hysteresis comparator and sector number generation. Previously, DC machines were preferred for variable speed drives. However, DC motors have disadvantages of higher cost, higher rotor inertia and maintenance problem with commutators and brushes. In addition they cannot operate in dirty and explosive environments. The AC motors do not have the disadvantages of DC machines. Therefore, in last three decades the DC motors are progressively replaced by AC drives. The responsible for those result are development of modern semiconductor devices, especially power Insulated Gate Bipolar Transistor (IGBT) and Digital Signal Processor (DSP) technologies. The most economical IM speed control methods are realized by using frequency converters. Many different topologies of frequency converters are proposed and investigated in a literature. However, a converter consisting of a diode rectifier, a dc link and a Pulse Width Modulated (PWM) voltage inverter is the most applied used in industry.

When describing a three-phase IM by a system of equations the following simplifying assumptions are made:

- the three-phase motor is symmetrical,
- only the fundamental harmonic is considered, while the higher harmonics of the spatial field distribution and of the magnetomotive force (MMF) in the air gap are disregarded,
- the spatially distributed stator and rotor windings are replaced by a specially formed, so-called concentrated coil,
- the effects of anisotropy, magnetic saturation, iron losses and eddy currents are neglected,
- the coil resistances and reactance are taken to be constant,
- in many cases, especially when considering steady state, the current and voltages are taken to be sinusoidal.

II. SVM DIRECT TORQUE CONTROL

A. Overview

In conventional simple DTC systems, the torque error and flux error are used for the generation of next switching condition of the two-level inverter. However, the SVM-DTC involves the determination of the power switch conduction times in each modulation period, leading to controlled switching frequency DTC technique [3]. The SVM method uses a special switching scheme of the six power transistors of a 3-phase inverter. In fact the SVM technique involve eight rules for switching modes of inverter to control the stator flux to move with the reference flux vector in circle. It achieves the higher controlling. Eight types of switching modes are corresponding respectively to eight space voltage vectors that contain six active voltage vectors and two zero voltage vectors. The axes of hexagon contain six active voltage vectors. And at the origin there are two zero voltage vectors. All these are the basic space vectors [3]. In short the SVM-DTC method selects one of the six nonzero and two zero voltage vectors of the inverter on the basis of the instantaneous errors in torque and stator flux magnitude. These sectors are shown in Fig 1.

![Figure 1. Basic switching vectors and sectors.](image)

Voltage vectors, produced by a PWM inverter, divide the space vector plane into six sectors and each sector is represented as:

\[(i - 1) \frac{\pi}{3} < \theta_i \leq \frac{i \pi}{3}, i = 1...6 \ldots \ldots \ldots (1)\]

The reference voltage vector is determined by the following equation:

\[\theta_v = \arctan\left(\frac{v^*_{\beta}}{v^*_{\alpha}}\right) \ldots \ldots \ldots (2)\]

The principle used by SVM is to project the desired stator voltage vector \(V_{\text{ref}}\) on the two adjacent vectors \(V_i\) and \(V_{i+1}\) corresponding to two switching states of the inverter [4]. By these projections the required commutation time \(T_i\) and \(T_{i+1}\) is calculated and further for inverter the two non-zero switching states are calculated by these values. For maintaining
the constant commutation frequency, in the case where $T_i+T_{i+1} \leq T_{mod}$, a zero state of the inverter is applied during the rest of the period $T_{mod}$, i.e. $T_0 = T_{mod} - (T_i+T_{i+1})$. The explanation here is for sector S1, as presented in Fig 2. As the reference voltage vector $V_{sref}$ is in sector S1, it can be the result of the active voltage vectors $V1$ and $V2$ [4]. The projection on these adjacent vectors are represented by following equation:

$$V_{sref} = V_s* \alpha + j V_s* \beta = \frac{T_1}{T_{mod}} V1 + \frac{T_2}{T_{mod}} V2 \ldots (3)$$

Where $T_{mod} = T1 + T2 + T0$. $D1$ and $D2$ are duties relative to voltages $V1$ and $V2$ [4].

For generating the error signal the reference flux and estimated flux are compared and this error signal is applied to PI flux controller to calculate the value of d-axis of the voltage [7]. The d-axis voltage can be derived as:

$$V_{sd} = k_p \left( \Delta \psi + \frac{1}{\tau_i} \int \Delta \psi dt \right) \ldots (6)$$

Where $\Delta \psi = \psi_{ref} - \psi_{estimated}$

After these the d and q frames are converted to $\alpha$ and $\beta$ by Inverse park transformation and then inputted to SVM block. The signal generated at the output of SVM block is the control signal for inverter which is further applied to inverter gates and the speed of induction motor is forced toward the reference.

### B. Flux and Torque Estimator

This block calculate the flux and torque from the terminal voltage and current of machine and then the sector number is derived for the flux vector. The voltage and current in dq frame are given in below equations [6].

$$v_{ds} = \frac{1}{\sqrt{2}} (v_a - v_b) \ldots (7)$$

$$v_{qs} = \frac{1}{\sqrt{2}} (2v_a - v_b - v_c) \ldots (8)$$

$$i_{ds} = -\frac{1}{\sqrt{2}} (i_a + 2i_b) \ldots (9)$$

$$i_{qs} = i_a \ldots (10)$$

The elements of stator flux are represented as:
The magnitude of stator flux can be calculated as:

\[ \psi_{ds} = \int (v_{ds} - i_{ds}R_d) \, dt \]  

(11)

\[ \psi_{qs} = \int (v_{qs} - i_{qs}R_d) \, dt \]  

(12)

The magnitude of stator flux can be calculated as:

\[ \psi = \sqrt{\psi_{ds}^2 + \psi_{qs}^2} \]  

(13)

By using the stator flux components the flux vector zone can be derived. From flux component, current component and the number of poles of the machine the electromagnetic torque can be calculated as:

\[ T_e = \frac{3P}{2} (\psi_{ds}i_{qs} - \psi_{qs}i_{ds}) \]  

(14)

### C. Speed Controller

In this block an error signal is generated from actual and reference speed, and this error signal is applied to PI controller which process it and give output as a reference torque.

### III. SIMULATION AND RESULTS

The Simulation of SVM-DTC circuit is performed for the step inputs of speed reference and load torque. The reference speed is given as 500rpm for 0 to 1.5sec, 250rpm for 1.5 to 3sec, -250 for 3 to 4.5sec and -500rpm after 5sec of time. The load torque is applied as 0Nm for 0 to 2sec, 700Nm for 2 to 3.5sec and -700 after 3.5sec.

![Figure 4. Stator current, Rotor Speed & Rotor Torque.](image)

The simulation results is obtained for the stator current, rotor speed and torque. The simulation results are shown in Fig 4 & Fig 5. From Fig 4, it is cleared that the speed and torque of motor is controlled as required and the torque ripples are reduced to a very low level.

![Figure 5. Locus of the Stator Flux.](image)

### IV. CONCLUSION

In this paper the direct torque control of Induction Motor is completed using SVM and PI controller and the results and evaluation is completed with Matlab/Simulink application. If we see to outcomes’s graph the Rotor speed is controlled very thoroughly and the certain applied reference speed is achieved. And it work for each of positive and negative reference value, implies that it work in four quadrants. Most effective a small ripple is show up when a large change is arise in reference but that is no longer a countable ripple. The identical is arise to rotor torque. The Rotor achieve the burden torque very swiftly. It offers quality results also for the torque controlling. So for that reason the SVM and PI based Direct Torque control process is a satisfactory method for controlling the Induction Motor.

### REFERENCES


Author’s Profile

V. Kiranmaye working as Asst. Professor, Department of EEE in Kamala Institute of Technology and Science, Karimnagar. My Areas of Interest are Drives, operation and control of machines.

G. Naresh completed M.E., My Areas of Interest are Power flow control in drives, operation and control of machines.

Bhukya Ravi completed M.E., My Areas of Interest is Power Electronic Converters.