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Analysis, Modeling and Control of Induction Motor by using Space Vector Topology

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***Abstract*— The most efficient control method for the induction motor is present here, that is vector control method. This include dynamic model of induction motor in any reference frame, vector control by dynamic model and appropeate space vector pulse width modulation generation. This result into high performance of induction motor (IM) drive using space vector method (SVM). Indirect field oriented control (IFOC) is produce high performance in IM drive using decoupling the rotor flux and torque producing current component of stator current. Batter control can be obtained by PI controller and SVM method.**

***Index Terms*—** PWM inverter, modulation, gate pulse, MOSFET.

I. Introduction

AC induction motor is more popular in the industries because of the robust construction, moment of inertia is low, ripple torque is low and high torque. IM use widely in steel mills, machine tools, sand paper mills etc. some method of the control is used for drive in high performance applications [1]. In this paper concept related to decoupled rotor flux and torque is given based upon the magnetizing current component. This valid for only steady state condition. Appling the PI controller and SVM method, decoupled control system can use for perform in transient and steady state condition both[2].

Space vector PWM method is most advantageous among all PWM technique. Space vector PWM (SVM) method advanced computation intensive PWM method [3]. For the variable frequency drive PWM topology is best option because of its excellent performance. SVM theory based on rotating space vector optimizes the harmonics. It is somewhat different than PWM topology, it consider inverter as a single unit. PWM consider it as a separately.
Modulation accomplished by the switching period or state of inverter. SVM is topology based on digital modulation. Its aim is to produce PWM load line voltage.

Scalar control provides variation in control of magnitude. For example; flux and torque control is obtained by controlling the voltage and Slip/Frequency of the machine respectively. Scalar-control drives have somewhat inferior performance.

II. Vector Control of Induction Motor with Flux Estimation.

If we want the vector type control of the induction motor then the voltage or current model of the induction motor is necessary. In that stator voltage or stator current use for calculating estimated flux. Unit vector $\cos\theta_e$ and $\sin\theta_e$ for necessary transformation[4].

In figure 1 that is block diagram of flux estimation by using current model. Torque reference T_e* is produced by the error produced by proposed integral (PI) controller. V_{ds} and V_{qs} command voltage achieved by flux and torque control loop using PI controllers. Equation for stationary frame is as below.

$$V_{qs} = i_{qs} R_s + \frac{d\lambda_{qs}}{dt} \quad (1)$$

The estimated flux is given as,

$$\lambda_{ds} = \frac{L_m i_{ds}}{1+sT_r} \quad (2)$$

The slip speed is as below,

$$W_{sl} = \frac{L_m i_{ds}}{\lambda_{ds} T_r} \quad (3)$$

The estimated torque given as

$$T_{e(sest)} = \frac{3}{2}\frac{P}{2}(\lambda_{ds} i_{qs} - \lambda_{qs} i_{ds}) \quad (4)$$

Since $\lambda_{qr} = 0$, for decoupling control we have a torque equation as [5].

$$T_{e(sest)} = \frac{3}{2}\frac{P}{2}\lambda_{ds} i_{qs} \quad (5)$$

Control loop torque and output flux, for example torque and flux PI controller are voltage component that control the I_{ds} and I_{qs} respectively. That adding decoupling voltage components $V_{ds(Decouple)}$ and $V_{qs(Decouple)}$ for achieve direct and quadrature components of voltage that is V_{ds}^* and V_{qs}^*.

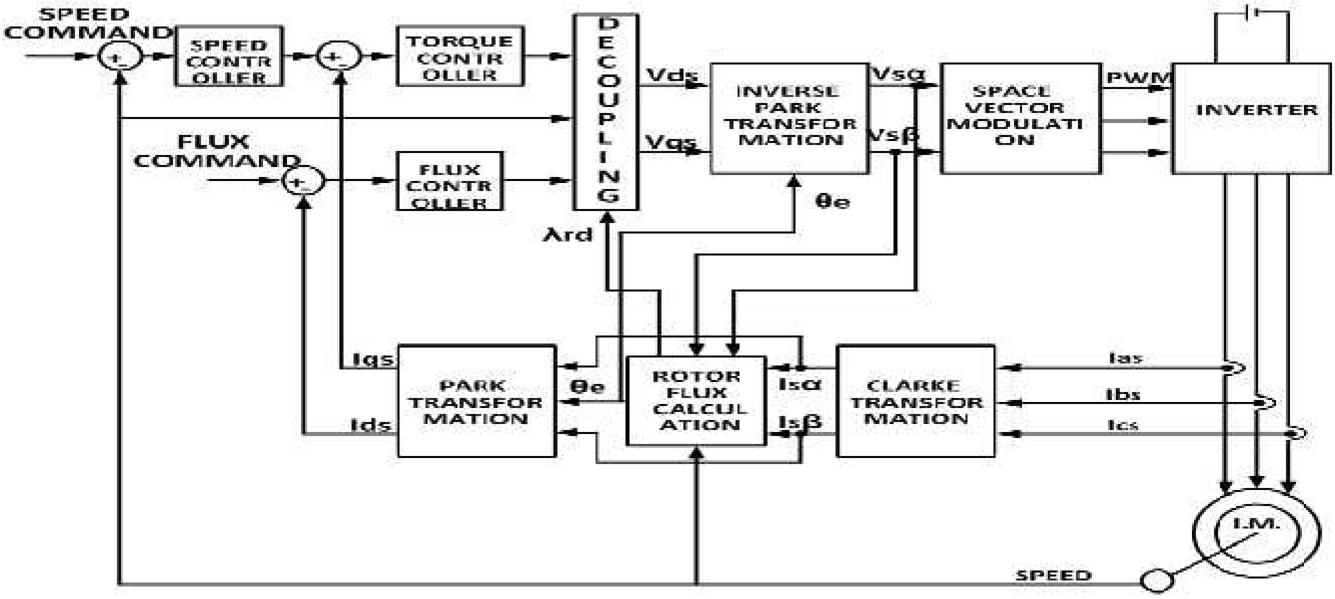


Fig. 1 Schematic of Vector control of induction motor with Flux estimation

$$V_{QS(DECOUPLE)} = -W_R I_{QS}\left(L_S - \frac{L_m^2}{L_r}\right) \quad (6)$$

$$V_{qs(decouple)} = W_r\left[i_{ds}\left(L_s - \frac{L_m^2}{L_r}\right) + \lambda_{ds}\frac{L_m}{L_r}\right] \quad (7)$$

V_{ds}^* and V_{qs}^* after going through transformation are converting to the α – β components that are, V_α and V_β that fed as input quantity to the space vector PWM control block for necessary switching states of inverter related to the induction motor [6].

III. SPACE VECTOR MODULATION

Space vector modulation becomes a standard of switching converter and important research effort. Variation slope of the current is doubled when the phase voltage gets doubled. The maximum value of phase current is herein denoted with I_M. During the time interval of [t3, t4] the output voltage vector is V_3. In the general case of three phases R-L load the current space vector can be defined by analyzing each voltage switching vector effect. Decomposing the current space vector expression on the *real* and *image* axes helps us to demonstrate that the current vector trajectory is a continuous function during each time interval for which the voltage is constant. Since the voltage space vector changes its position on discrete positions at each 60 degrees, the current space vector trajectory results close to hexagonal for large inductances [7].

Space vector PWM give input to the AC machine with required phase voltages. SVPWM topology generating the pulse signal fits the necessary requirement and harmonics. Harmonic contents determine the copper losses of machine. That taking into account the two constraints quoted above 8 possible switches commands. These 8 switch combinations determine 8 phase voltage configurations. This 8 switch Combination emphasis 8 phase of voltage. This can be easily understood by below combination [8].

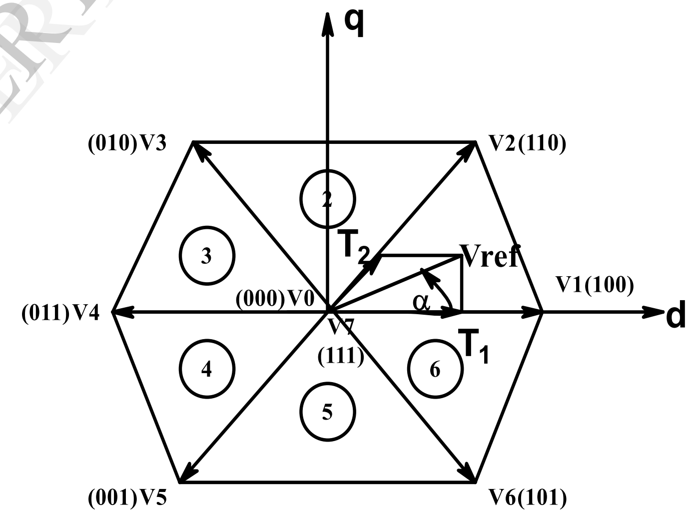


Fig. 2 Hexagonal structure including sectors

The vectors are dividing the whole plan into the six sectors. On that sector that the voltage reference, any two adjacent vectors are pick. Binary representation of that two basic vector differ in only one bit, only one of the upper transistors switch when switching pattern moves from any one vector to adjacent one. Two vectors that are time weighted in sample period T use for generate desired output voltage [9].

Three phase a-b-c voltages are converting into desired d-q component for achieving reference vector Vref that's magnitude and angle are used for generating into sector. 8 space vector include 6 active vectors (V_1 to V_6) and two zero

vectors (V_0 and V_7). Active vectors feed the voltage to induction motor where zero vectors feed zero voltage to the load [10].
To finding the value of Vd, Vq, Vref, and angle (α) below equation are used [11].

$$\begin{bmatrix} V_d \\ V_q \end{bmatrix} = \frac{2}{3}\begin{bmatrix} 1 & \frac{-1}{2} & \frac{-1}{2} \\ 0 & \frac{\sqrt{3}}{2} & \frac{-\sqrt{3}}{2} \end{bmatrix}\begin{bmatrix} V_{an} \\ V_{bn} \\ V_{cn} \end{bmatrix} \quad (8)$$

$$|\overline{V_{ref}}| = \sqrt{V_d 2 + V_q 2} \quad (9)$$

$$\alpha = \tan^{-1}\left(\frac{V_q}{V_d}\right) = \omega t = 2\pi f t \quad (10)$$

where f = fundamental frequency.

Switching time duration for any sector is given as [12].

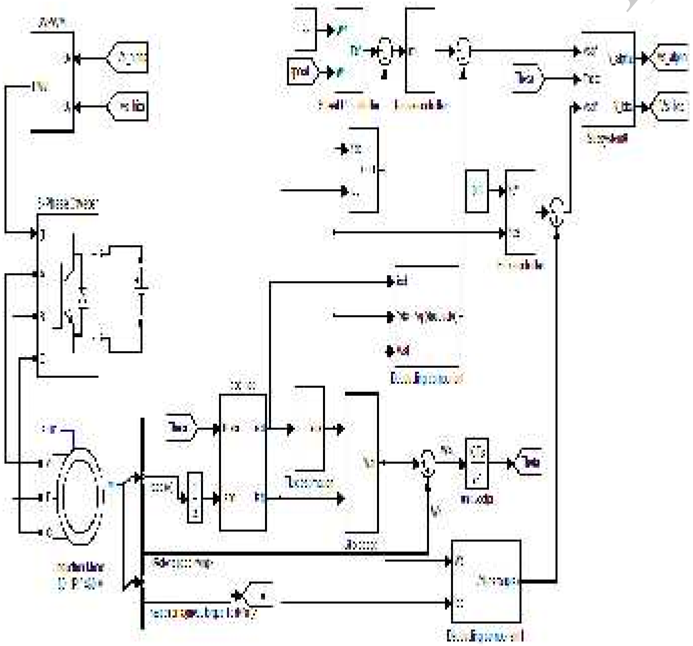
$$T_1 = \frac{\sqrt{3}T_z |\overline{V_{ref}}|}{V_{dc}}\left(\sin\frac{n}{3}\pi\cos\alpha - \cos\frac{n}{3}\pi\sin\alpha\right) \quad (11)$$

$$T_2 = \frac{\sqrt{3}T_z |\overline{V_{ref}}|}{V_{dc}}\left(-\cos\alpha\sin\frac{n-1}{3}\pi + \sin\alpha\cos\frac{n-1}{3}\pi\right) \quad (12)$$

$T_0 = (T_Z - (T_1 + T_2))$ and n = 1 to 6, (sector 1 to 6) (13)

$(0 \le \alpha \le 60^0)$

III. SIMULATION USING MATLAB



IV. RESULTS AND ANALYSIS

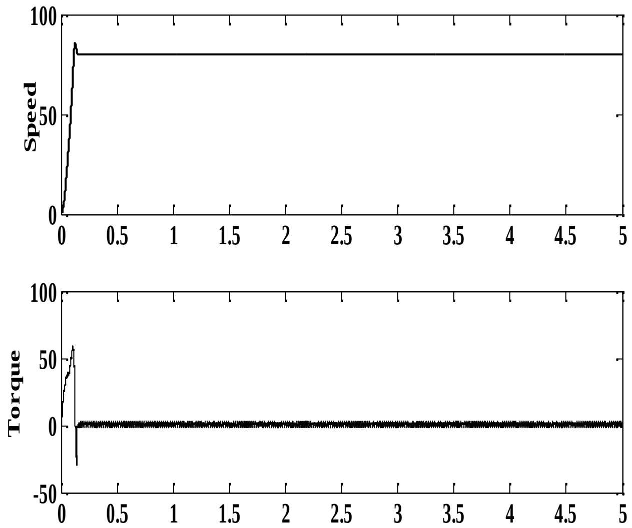
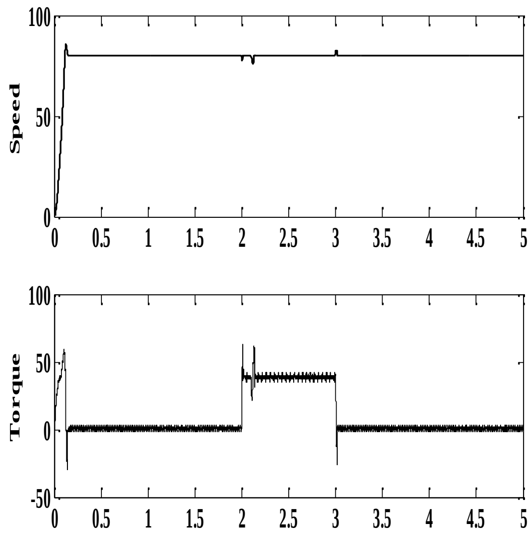


Fig. 3 Result of speed and torque without load torque

The simulation of a SVPWM based induction motor drive with flux estimation is done. PI speed and flux estimation is obtained from above simulation. Steady state performance is above result shows the time period of speed is decrease about 0.2 sec. The initial overshoot of the speed during settling time is nearly about 15% of rated speed.



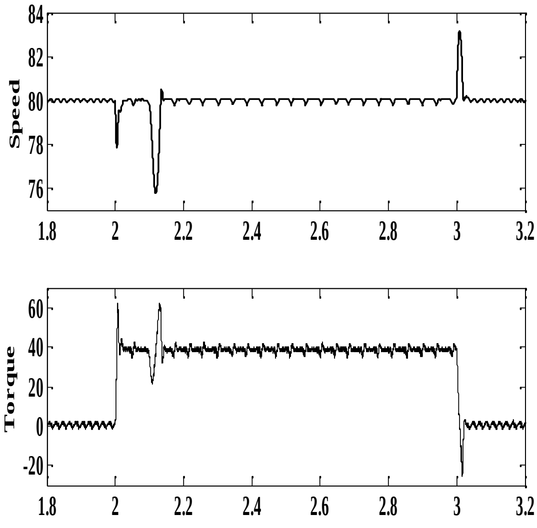


Fig. 4 Result of speed and torque with load torque Tl = 38 NM

Result above clearly describes that dynamic load rejection capability on the drive. The load torques applied at the 2 sec. which result in a drop of small speed while maintain nearly constant speed when load torque is relished at 3 sec. The resulting torque disturbance peak also observed. The speed suffers with a small droop at load application and instant overshoot at load removal to regain the speed reference. Torque pulsation can be seen considerably decrees even under disturbing load condition.

V. CONCLUSION

Space vector based induction motor drive give good steady state and also dynamic response with the quick settling of speed and capability related to load disturbance rejection. Close loop flux estimation give enhanced dynamic behavior because of PI speed and flux controller. Dynamic load application and removal give result in peak speed fall and rise. This gives vector controlled drive that can be used in high performance applications.

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