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Simplified SVPWM Algorithm for Vector Controlled Induction Motor Drive Using the Concept of Imaginary Switching Times

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***Abstract*—This paper presents simplified space vector pulse width modulation (SVPWM) based vector controlled induction motor drive. The conventional SVPWM algorithm constructs the required voltage vector in the average sense by using active and zero voltage vectors. Moreover, complexity involved in conventional SVPWM algorithm is more. Whereas, the proposed SVPWM algorithm calculates the switching times using the concept of imaginary switching times. The proposed algorithm does not need the calculation of sector and angle information. To validate the proposed algorithm, simulation studies have been carried out on vector controlled induction motor drive and the results are presented in this paper.**

***Index Terms*—imaginary switching times, SVPWM, vector control**

I. Introduction

The development of high speed power switching devices has brought high frequency switching operations to power electronic equipments and has improved the dynamic performance of inverter fed ac drives. Many schemes have been proposed for the speed control [1] of induction motor drives, among which the vector control is most effective method.

However, the current controlled vector control induction motor drive uses hysteresis controllers, which causes variable switching frequency of the inverter. This problem can be overcome by using SVPWM algorithm [2]. The conventional SVPWM algorithm [3-4] uses two zero voltage vectors and two active voltage vectors in each sector to obtain the required reference voltage vector. Hence, the complexity involved in conventional SVPWM is more. To reduce the complexity involved in conventional SVPWM algorithm, a simplified approach is developed in [5] by using the concept of offset time. Moreover, imaginary switching times based SVPWM algorithm is used in [6].

This paper presents an imaginary switching times based SVPWM algorithm for vector controlled induction motor drive. In the proposed algorithm, the zero vector time is distributed by using a factor k_0.

II. Modeling of Induction Motor

The mathematical model of a three-phase, squirrel-cage induction motor is described by equations in stationary rotating reference frame, and the equations are given by (1) – (3)

$$\begin{bmatrix} v_{qs} \\ v_{ds} \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} R_s + L_s p & 0 & L_m p & 0 \\ 0 & R_s + L_s p & o & L_m p \\ L_m p & -\omega_r L_m & R_r + L_r p & -\omega_r L_r \\ \omega_r L_m & L_m p & \omega_r L_r & R_r + L_r p \end{bmatrix} \begin{bmatrix} i_{qs} \\ i_{ds} \\ i_{qr} \\ i_{dr} \end{bmatrix} \quad (1)$$

where $\omega_r = \dfrac{d\theta}{dt}$ and $p = \dfrac{d}{dt}$

The electromagnetic torque of the induction motor in stator reference frame is given by

$$T_e = \frac{3}{2}\left(\frac{P}{2}\right)\left(\psi_{ds} i_{qs} - \psi_{qs} i_{ds}\right) \quad (2)$$

The electro-mechanical equation of the induction motor drive is given by

$$T_e = T_L + J\frac{d\omega_m}{dt} = T_L + \frac{2}{P} J \frac{d\omega_r}{dt} \quad (3)$$

III. SVPWM Based Vector Control Algorithm

The block diagram of vector controlled induction motor drive using the SVPWM algorithm is given in Fig. 1. Command currents i_{ds}^* and i_{qs}^* in the vector control are compared with the respective i_{ds} and i_{qs} currents generated by the transformation of phase currents with the help of the unit vector. From the respective errors, the voltage command signals can be generated through PI controllers. These voltage commands are then converted into stationary frame and given to SVPWM block.

In the proposed SVPWM algorithm, the d-axis and q-axis voltages are converted into three-phase instantaneous reference voltages. Then the imaginary switching time periods proportional to the instantaneous values of the reference phase voltages which are defined as

$$T_{as} = \left(\frac{T_s}{V_{dc}}\right)V_{as}^* ; T_{bs} = \left(\frac{T_s}{V_{dc}}\right)V_{bs}^* : T_{cs} = \left(\frac{T_s}{V_{dc}}\right)V_{cs}^* \quad (4)$$

where T_s and V_{ds} are the sampling interval time and dc link voltage respectively. Here, sampling frequency is the twice the carrier frequency.

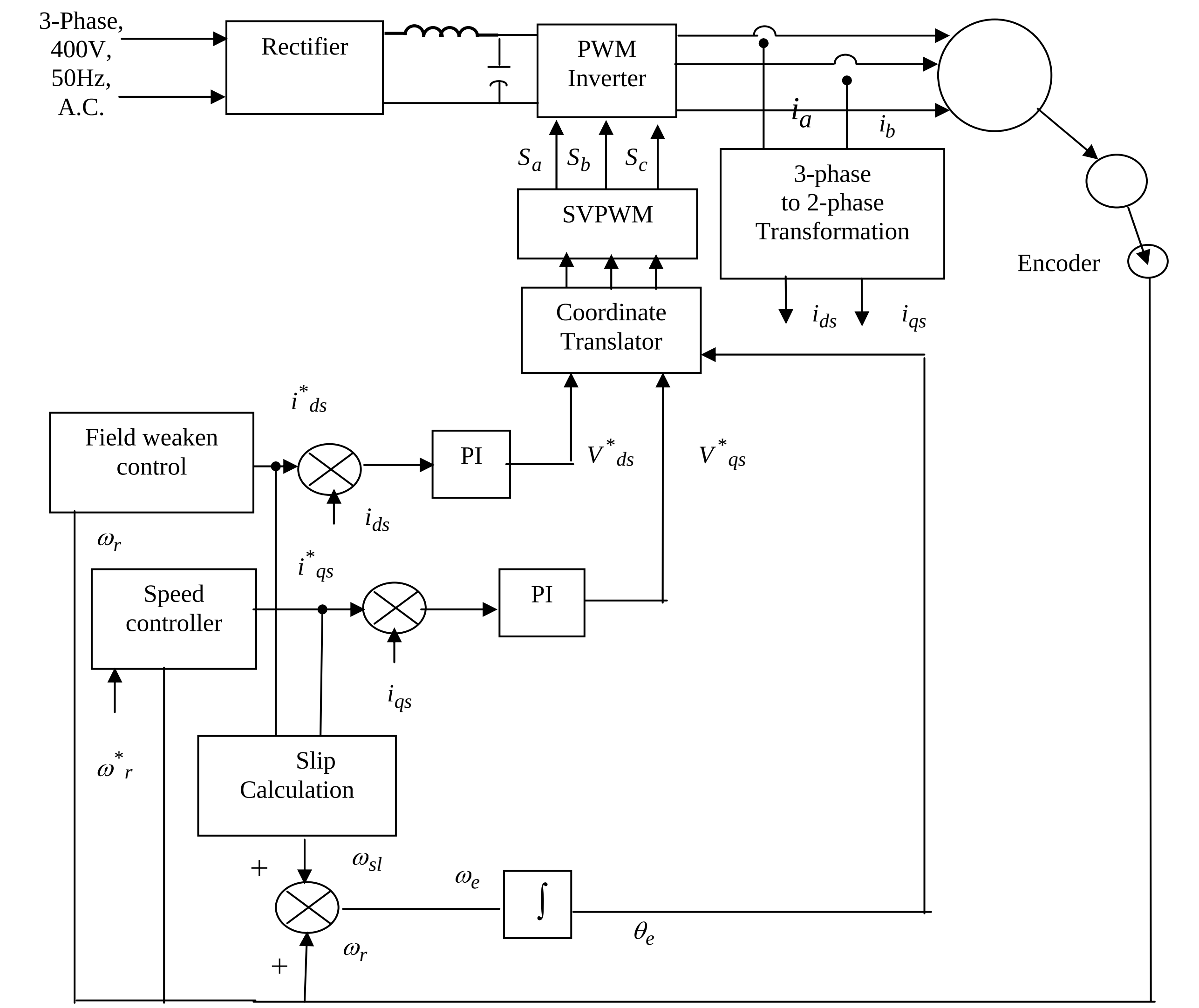

Fig. 1 Proposed SVPWM based vector control of induction motor

Then the maximum, middle and minimum imaginary switching times can be found in each sampling interval by using (5) - (7).

$$T_{\max} = Max\left(T_{as},\ T_{bs},\ T_{cs}\right) \quad (5)$$

$$T_{\min} = Min\left(T_{as},\ T_{bs},\ T_{cs}\right) \quad (6)$$

$$T_{mid} = Mid\left(T_{as},\ T_{bs},\ T_{cs}\right) \quad (7)$$

The active voltage vector switching times T_1 and T_2 are calculated by using (8).

$$T_1 = T_{Max} - T_{Mid} \text{ and } T_2 = T_{Mid} - T_{Min} \quad (8)$$

The zero voltage vectors switching time is calculated using (9).

$$T_Z = T_s - T_1 - T_2 \quad (9)$$

In the proposed algorithm, the zero state time will be shared between two zero states as T_0 for V_0 and T_7 for V_7 respectively, and can be expressed as [7]

$$T_0 = k_o T_z \quad (10)$$

$$T_7 = (1 - k_o)T_z \quad (11)$$

Various PWM algorithms can be generated by changing k_o between zero and one. However, this paper presents only SVPWM algorithm, which distributes the zero voltage vector time equally among V_0 and V_7. Hence, here k_0 is taken as 0.5 to obtain the SVPWM algorithm. Thus, the proposed algorithm does not use sector and angle information to calculate the switching times.

IV. H Simulation Results and Discussion

To validate the proposed method, simulation studies have been carried out by using Matlab/Simulink. The motor parameters are as follows:

Stator resistance R_s = 4.1ohm, rotor resistance R_r = 2.5ohm, stator inductance L_s=0.545H, rotor inductance

L_r=0.542H, mutual inductance L_m=0.51H, moment of inertia J=0.04Kg-m^2.

The simulation results of the proposed drive are shown in Fig. 2 – Fig. 6. The starting and steady state plots are given in Fig. 2and Fig.3. Fig. 4 shows the transients during the step change in load torque command (here the load torque of 8 N-m is applied at 0.6 sec and removed at 0.8 sec). The transients of the drive during speed reversals are given in Fig.5 and Fig.6. From the simulation results, it can be observed that the proposed drive gives good performance with simplified SVPWM algorithm. Thus, with the proposed algorithm, constant switching frequency operation can be obtained when compared with the conventional vector control algorithm, where the hysteresis current controllers are used. Moreover, the proposed algorithm reduces the complexity involved in calculation of switching times.

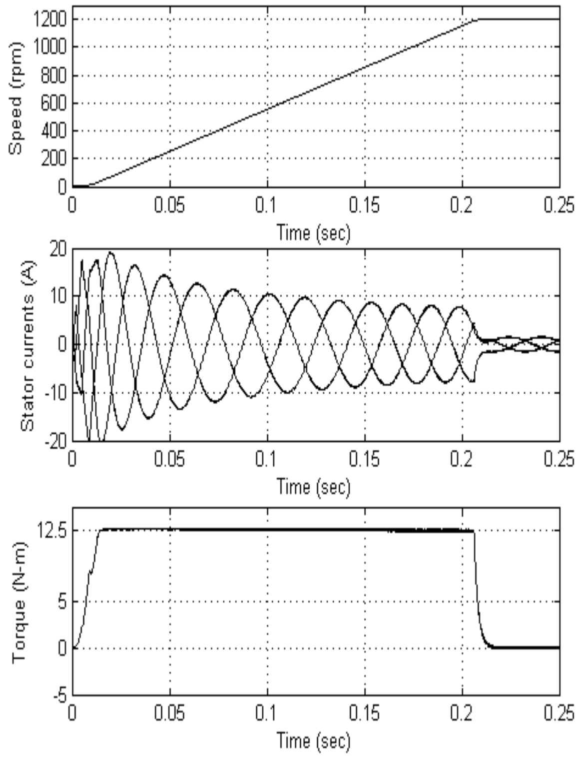

Fig. 2 Starting transients of the proposed drive

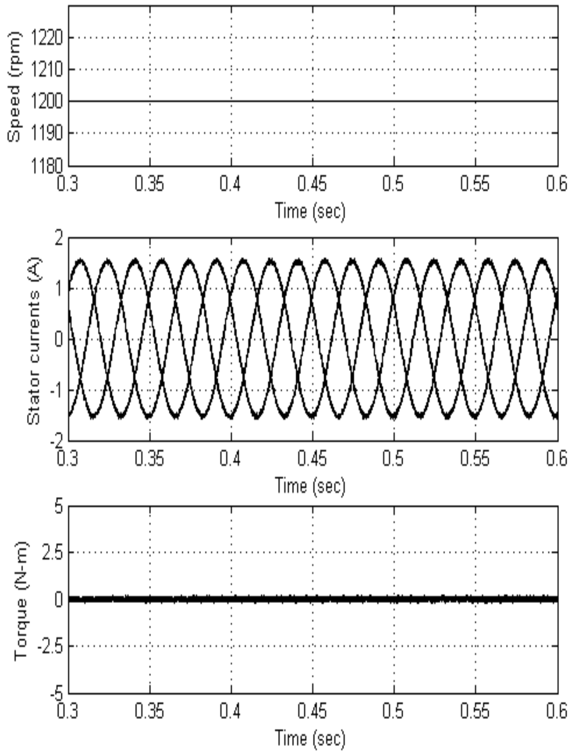

Fig. 3 Steady state transients of the proposed drive

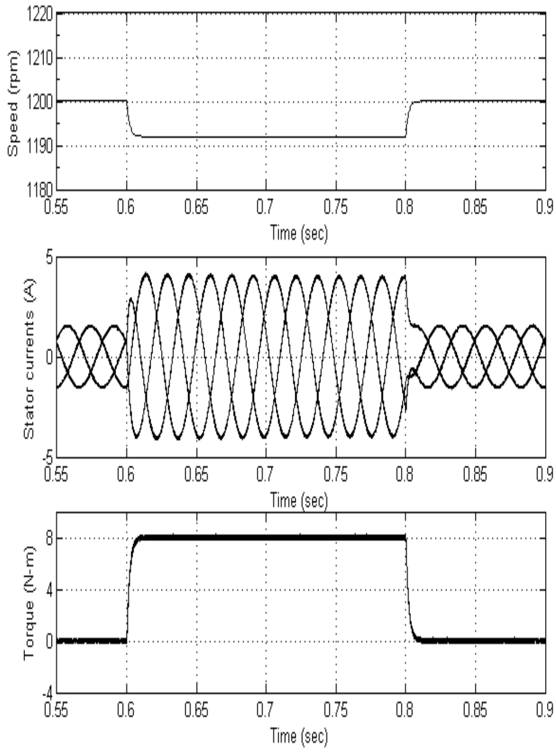

Fig.4.transients during step change in load torque

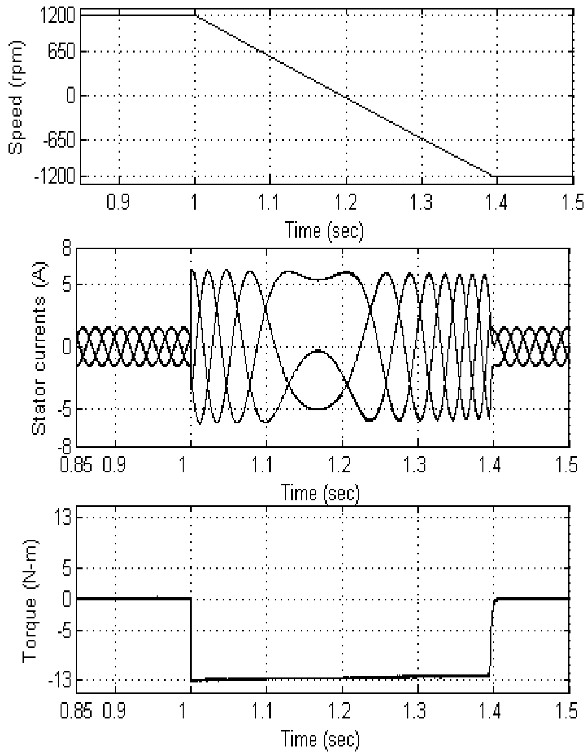

Fig. 5 Transients during speed reversal operation (Speed is changed from +1200 rpm to -1200 rpm)

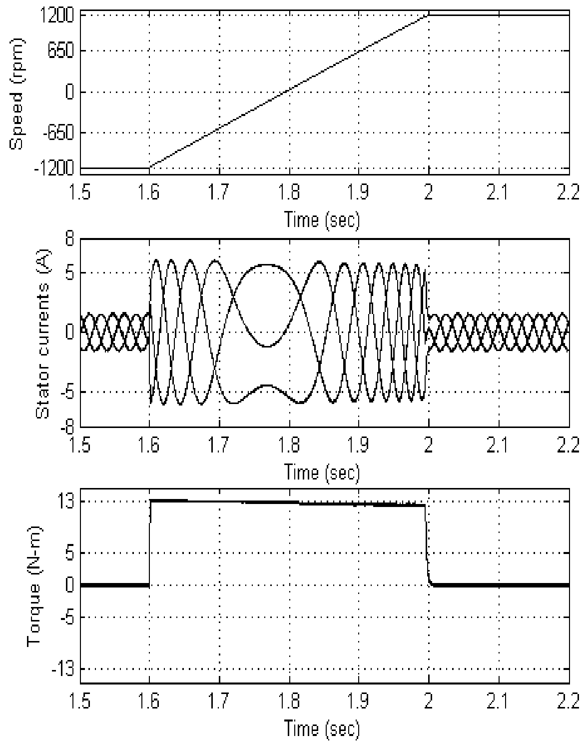

Fig. 6 Transients during speed reversal operation (Speed is changed from -1200 rpm to +1200 rpm)

V. Conclusions

The conventional current controlled vector control algorithm gives large ripple and varying switching frequency operation. To overcome these problems, this paper presents a simplified SVPWM algorithm using the concept of imaginary switching times.

The proposed SVPWM algorithm does not use sector and angle information. Thus, the proposed algorithm reduces the complexity involved in the conventional SVPWM algorithm and also improves the drive operation. The simulation results show the validity of the proposed algorithm.

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