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Comparison study of Vector Control of Induction Motor Using Rotor Flux Estimation by Two Different Methods

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Abstract

The Speed Control of Induction motor is one of the important areas of research for the Electrical Engineers. Since the requirement and industrial applications of induction motors cannot be neglected, their fine speed control is one of the major objectives for the control drive engineers. The vector control of induction motors provide one of the most suitable and popular speed control technique presently used. The scalar control techniques available on the contrary were simple to implement but have the coupling effect ultimately responsible for the sluggish response which further made system prone to instability due to higher order system effect. This paper will show the comparison of vector control using PI Controller with the rotor flux estimation by two different methods and the analysis. The simulation study of results will form the basis of the conclusion.

Keywords: Vector Control, Speed Control, Scalar Control, Sluggish, Higher Order System Effect, PI Controller, Rotor Flux.

1. Introduction

An induction motor is an asynchronous AC (Alternating current) motor. The least expensive and most widely used induction motor is the squirrel cage induction motor. The interest in sensorless drives of induction motor has grown significantly over the past few years due to some of their advantages, such as mechanical robustness, simple construction and less maintenance. These applications include pumps and fans paper and textile mills, subway and locomotive propulsions, electric and hybrid vehicles, machine tools and robotics, home appliances, heat pumps and air conditioners, rolling mills, wind generation systems etc. So the induction motors have been used more in the industrial variable speed drive system with development of vector control. This method requires a speed sensor such as shaft encoder for speed control.

The control and estimation of ac drives in general are considerably more complex than those of ac drives, and this complexity increases substantially if high performances are demanded.

2. Control schemes for speed control of three phase induction Motor

The different control schemes of induction motor drives are including scalar control, vector or field oriented control, direct torque control, and adaptive control etc. But induction motor control drives are broadly classified in two category i.e. scalar control and vector control.

2.1 Scalar Control

In this method the magnitude of the control variable is taken under variation irrespective of the coupling effect in machine. Scalar control is easy to implement, hence widely used in industries. But the performance of scalar controlled drives become inferior. To improve the performance of the scalar control method an encoder or speed tachometer is required to feed back the rotor angle or rotor speed signal and compensate the slip frequency. However, it is expensive and destroys the mechanical robustness of the induction motor. So these are the limitations of the scalar control which is overcome by Field Oriented Control or Vector Control of Induction motor drives.

2.2 Vector Control or Field Oriented Control (FOC)

Blaschke introduced the principle of vector control to realize the dc motor characteristics in an induction motor drive. For the same, he has used decoupled control of torque and flux in the motor and gives the name transvector control. In DC machine particularly separately excited dc motor, the field flux is perpendicular to the armature flux. Being orthogonal, these two fluxes produce no net interaction to each other. Adjusting the field current can therefore control DC machine flux, and the torque can be controlled independently of flux by adjusting the armature current. An ac machine is not so simple because of the interactions between the stator and rotor fields, whose orientations are not held at 90° but vary with operating conditions. We can obtain the DC machine like performance in holding a fixed and orthogonal orientation between the fields and armature fields in an AC machine by orienting the stator current with respect to rotor flux so as to attain independently controlled flux and torque. Such a scheme is called Vector Control or Field Oriented Control.

2.3 Indirect Vector control

There are essentially two general methods of vector control. One, called the direct or feed- back method, was invented by Blaschke [1], and the other, known as the indirect or feed forward method was invented by Hasse [2, 4].The two methods differ in the way the rotor angle is determined. In direct FOC the angle is obtained by the terminal voltages and currents, while as in indirect FOC, the angle is obtained by using rotor position measurement and machine parameter's estimation. Field orientation has emerged as a powerful tool for controlling ac machines such as inverter-supplied induction motors/synchronous motors. The dynamic performance of such drives is comparable to that of a converter fed four quadrant dc drives. The complex functions required by field oriented control are executed by intelligent controllers using microcontrollers or digital signal processors (DSP), thus greatly reducing the necessary control hardware [3, 6].

An important requirement to obtain good control performance is to make the motor parameters in the field-oriented controller coincide with the actual parameters of the motor. The ability to inject currents into the motor with a current source opened up new possibilities for parameter determination. It was Takayoshi [4] who described a new identification technique utilizing injected negative sequence components. It is shown that the stator as well as rotor resistance and leakage inductance can be determined on line while the motor is driving the load. The theory is verified with a full-scale hybrid computer simulation of a field-oriented controlled PWM inverter based induction motor drive.

2.4 Direct Vector Control

In direct FOC [5] the rotor angle or control vector is obtained by the terminal voltages & currents directly by using flux estimators. The direct vector control is also known as feedback vector control scheme. Similar to Indirect Vector Control, various controllers have been implemented on direct vector controlled induction motor drives also to improve the performance of the drive.

While the direct method is inherently the most desirable control scheme, it suffers from high cost and the unreliability of the flux measurement. Although the indirect method can approach the performance of the direct measurement scheme, the major weakness of this approach is centered upon the accuracy of the control gains which, in turn, depend heavily on the motor parameters assumed in the feed forward control algorithm.

3. Mathematical equations governing IMFOC

Axis transformation is governed by following set of equations [7]

$$I_{dq0} = TI_{abc} = \frac{2}{3}\begin{bmatrix} Cos\theta & Cos\left(\theta - \frac{2\pi}{3}\right) & Cos\left(\theta + \frac{2\pi}{3}\right) \\ -Sin\theta & -Sin\left(\theta - \frac{2\pi}{3}\right) & -Sin\left(\theta + \frac{2\pi}{3}\right) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix}\begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} \qquad \text{Eq. 1}$$

$$I_{abc} = Te^{-1} I_{dq0} = \frac{2}{3}\begin{bmatrix} Cos\theta & -Sin\theta & 1 \\ Cos\left(\theta - \frac{2\pi}{3}\right) & -Sin\left(\theta - \frac{2\pi}{3}\right) & 1 \\ Cos\left(\theta + \frac{2\pi}{3}\right) & -Sin\left(\theta + \frac{2\pi}{3}\right) & 1 \end{bmatrix}\begin{bmatrix} I_d \\ I_q \\ I_o \end{bmatrix} \quad \text{Eq. 2}$$

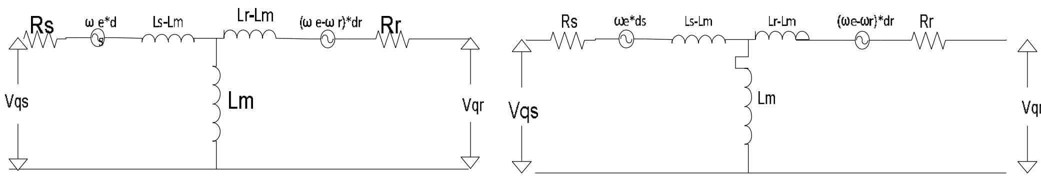

Fig. 1: Dynamic $d^e - q^e$ equivalent circuits of machine.

Voltage Equations are $V_{qs} = R_s * i_{qs} + \frac{d\psi_{qs}}{dt} + \omega_e \psi_{ds}$ Eq. 3

$$V_{ds} = R_s * i_{ds} + \frac{d\psi_{ds}}{dt} + \omega_e \psi_{qs} \quad \text{Eq.4}$$

$$V_{qr} = R_r * i_{qr} + \frac{d\psi_{qr}}{dt} + (\omega_e - \omega_r)\psi_{dr} \quad \text{Eq.5}$$

$$V_{dr} = R_r * i_{dr} + \frac{d\psi_{dr}}{dt} - (\omega_e - \omega_r)\psi_{qr} \quad \text{Eq.6}$$

Flux Equations are

$$\psi_{qs} = L_{ls} * i_{qs} + (i_{qs} + i_{qr})L_m \quad \text{Eq.7}$$

$$\psi_{qr} = L_{lr} * i_{qr} + (i_{qs} + i_{qr})L_m \quad \text{Eq.8}$$

$$\psi_{ds} = L_{ls} * i_{ds} + (i_{ds} + i_{dr})L_m \quad \text{Eq.9}$$

$$\psi_{dr} = L_{lr} * i_{dr} + (i_{ds} + i_{dr})L_m \quad \text{Eq.10}$$

4. Rotor Flux Estimation

In direct vector control method, it is necessary to estimate the rotor flux components ψ_{dr}^s *and* ψ_{qr}^s so that the unit vector and rotor flux can be calculated using equations

$$Cos\ \theta_e = \frac{\psi_{dr}^s}{\hat{\psi}_r} \quad \text{Eq. 11}$$

$$Sine\ \theta_e = \frac{\psi_{qr}^s}{\hat{\psi}_r} \quad \text{Eq. 12}$$

$$\hat{\psi}_r = \sqrt{\psi_{dr}^{s^2} + \psi_{qr}^{s^2}} \quad \text{Eq. 13}$$

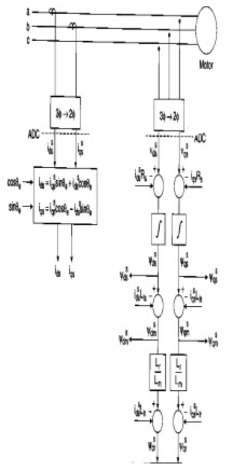

Fig. 3: Model from B.K. Bose

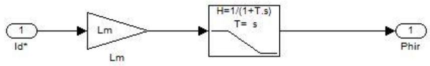

Fig. 4: Model using Constant

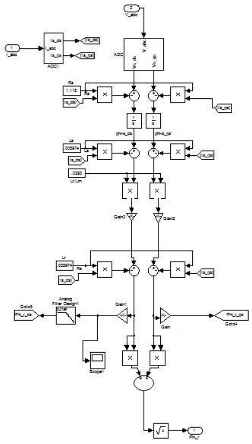

Fig. 5: Implemented Model from B.K. Bose

5. Simulation Results

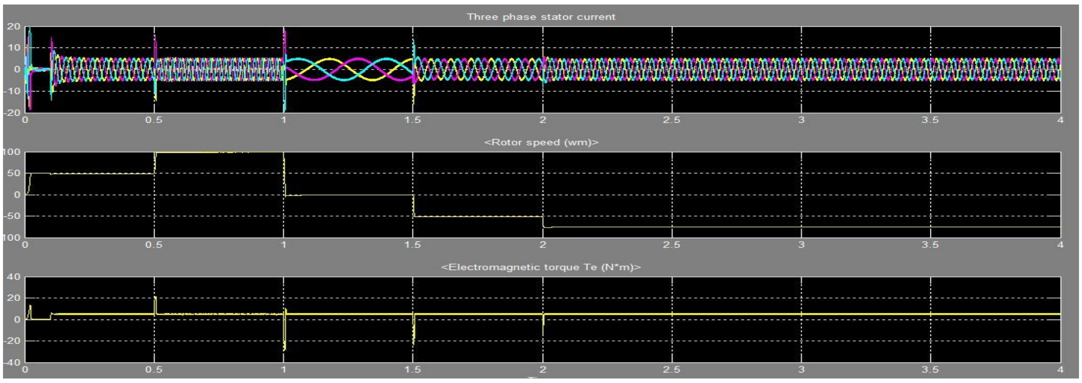

Fig. 4: Results 1 obtained using Rotor Flux Model.

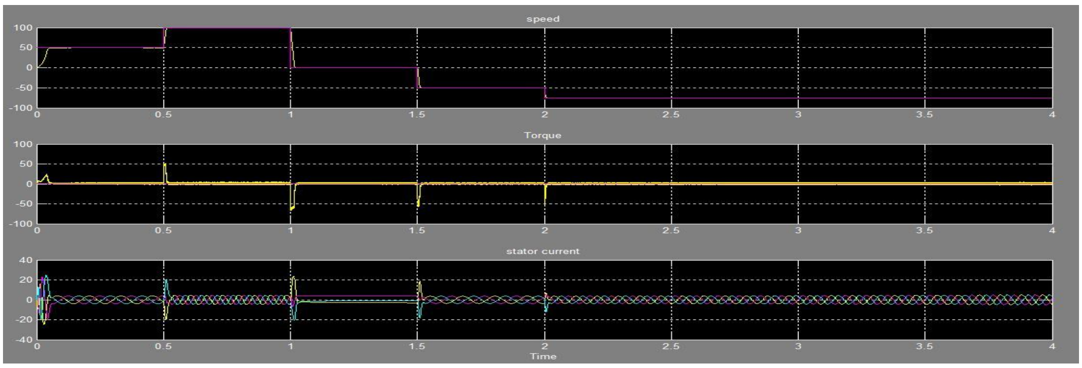

Fig. 5: Results 2 obtained using Rotor Flux Model.

6. Conclusion

From the above simulation results it was observed that the current waveforms are smoother as well as very less distortion in result 2 as compared to result 1. Moreover the torque waveforms are also better and the controller performance to track the reference speed is much more precise in results 2. Therefore it can be concluded that the vector control using model given in fig 5. It is obvious that the machine parameters and the PI controller parameters are same while performing the simulation in order to achieve the comparison.

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