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Performance Analysis of Three Phase Induction Motor Controlled Via Indirect Vector Control Using D Space 1104 R&D Controller Board

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Abstract

Electrical Drives today have become an important part of the modern industry. The motor drivesare used in very wide power range. In various applications where speed and position control is of great significance, the drives are controlled via a power electronic converter, an interface between the input power and the motor. Power consumption of the drive and the harmonics that it injects in the supply plays an important role in the overall performance of the drive. In this paper, a comparison of the power consumed in a 3 HP induction motor drive when controlled via PWM invertor is made with an uncontrolled motor running at same speed under same loading conditions and THD calculations for the both is done.

Keywords: Drives, PWM, harmonics, THD (Total Harmonic Distortion).

1. Introduction

The control and estimation of induction motor [7] drives constitute a vast subject, and the technology has further advanced in recent years. Induction motor drives with cage type machines have been the workhouse in the industry for variable speed application in a wide power range that covers from fractional kilowatts power to multi megawatts. 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. The energy saving aspect of variable frequency drives is getting a lot of attention now days.

The control and estimation of AC drives [7] in general are considerable more complex than those of DC drives, and this complexity increases substantially if high performance are demanded. The main reason of this complexity is need of variable frequency, harmonically optimum convertor power suppliers, the complex dynamics of AC machines, machines parameter variations[8], and difficulties of processing feedback signals in the presence of harmonics.

2. Types of Induction Motor Drives

The induction motor drives are broadly classified in two category i.e. Scalar control and Vector control.

2.1 Scalar control

Scalar control methods are basically simple and less accurate, and only the magnitude of control variable is altered. These methods are basically slow due to coupling effect of flux and torque.

2.2 Vector control or Field Oriented Control

At the present time, the field oriented control (FOC) technique or Vector control has widespread use in high performance induction motor drives. It allows, by means of co-ordinate transformation, to de couple the electromagnetic torque control from the rotor flux, and hence induction motor acts as a DC motor. In this technique, the variables are transformed into a reference frame in which the dynamic variables are like DC quantities. The decoupling control between the flux and torque allows induction motor to achieve fast transient response. Therefore, it is preferably used in high performance motor applications. Field Oriented control uses a vector model of the drive which is valid during transient operational so, which facilitates faster control of the drive.

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]

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

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

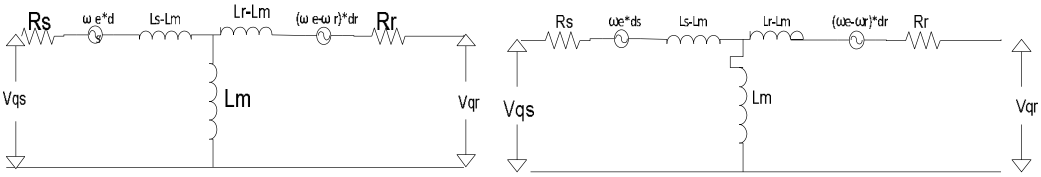

Fig. 1: Circuit diagram of induction motor after axis transformation.

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

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

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

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

Flux Equations are

$$\psi_{qs} = L_{ls} * i_{qs} + \left(i_{qs} + i_{qr}\right)L_m \qquad \text{eq.7}$$

$$\psi_{qr} = L_{lr} * i_{qr} + \left(i_{qs} + i_{qr}\right)L_m \qquad \text{eq.8}$$

$$\psi_{ds} = L_{ls} * i_{ds} + \left(i_{ds} + i_{dr}\right)L_m \qquad \text{eq.9}$$

$$\psi_{dr} = L_{lr} * i_{dr} + \left(i_{ds} + i_{dr}\right)L_m \qquad \text{eq.10}$$

4. Simulation & Hardware Implementation

Above schemes are implemented on a 3HP, 415 volt Induction motor drive which is controlled by IMFOC (indirect vector control) [4] using D space R&D controller board.

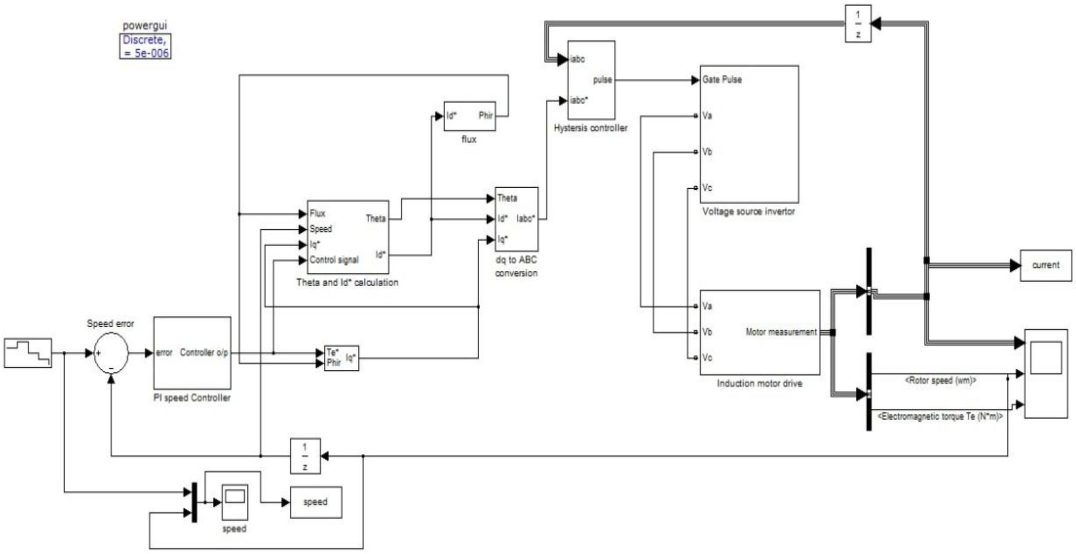

Fig. 2: Simulation model of 3HP, indirect vector controlled drive.

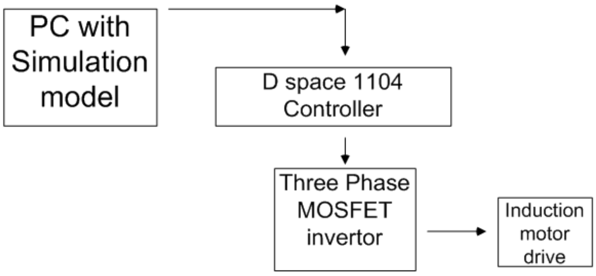

Fig. 3: Block diagram showing layout of Hardware Implementation.

5. Results

The simulation of the indirect vector controlled drive is presented below. The THD content in the current when motor was run with rated load is 34% and when motor was run without load is 9.009%. The higher percentage of THD is acceptable as FOC is variable frequency drive and hence THD calculated at base frequency of 50 Hz would always have a high value. In the Speed Vs. time characteristics, Dotted green line shows reference speed and darkens green line show actual speed of the motor.

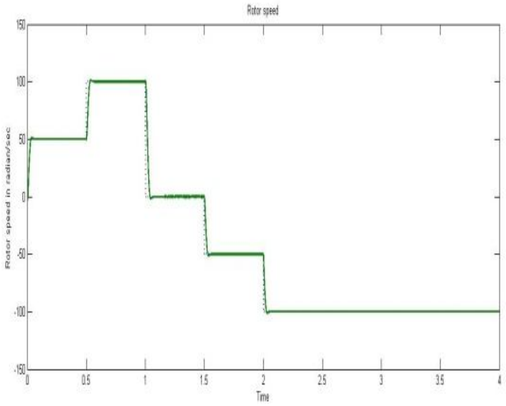

Fig. 2: Variation of Speed

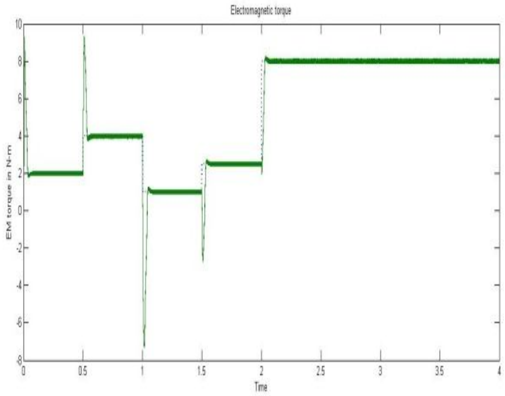

Fig. 3: Variation of Torque.

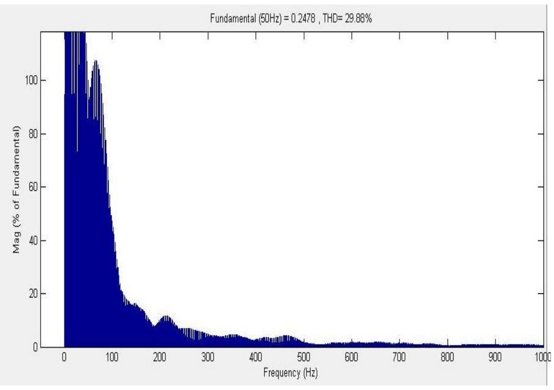

Fig. 4: THD when rated load is applied on motor

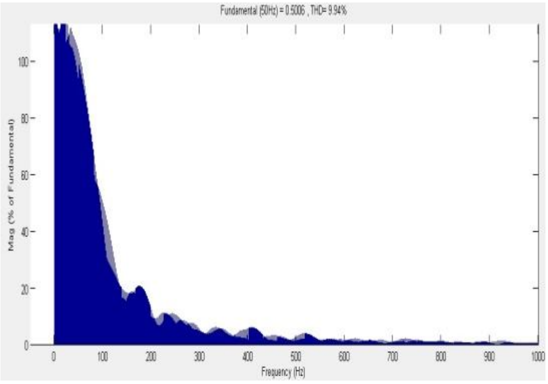

Fig. 5: THD when motor is run at No load.

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