

# Three-Phase Induction Motor Using Field-Oriented Control Under Various Conditions

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## ABSTRACT

*In order to achieve better induction motor drive control, a field-oriented control method is presented in this report. The proposed control strategy relies on separating a current space vector into two perpendicular components in order to constrain rotor flux and electrical torque individually. The PI controller should be used to correct the disparity between reference values and sensor feedback signals. A control motor drive model that uses field-oriented control simulates the recommended method. Different load scenarios are looked at to gauge the approach's success. The simulation results show how effective the field-oriented control strategy is in controlling speed.*

**Keywords:** field-oriented control, induction motor, speed control.

## 1. INTRODUCTION

Due to their straightforward and durable construction, high reliability, and affordable price across a variety of applications, induction motors (IM) is the most widely used machine in industrial applications. These days, with the advancement of power electronics and cutting-edge control approaches, IM drives have exceptional control capabilities [1].

In an IM drive system, the two primary methods for managing speed and torque are scalar control and vector control (VC). The most widely used scalar control technique, the voltage per hertz constant method, depends on changing the voltage and frequency to regulate the torque and speed of

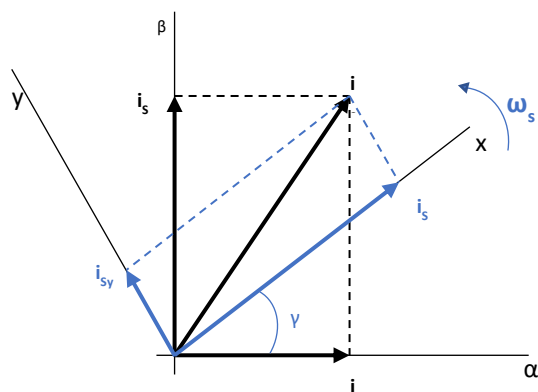
IM. The simplicity, low cost, and lack of dependence on sensor feedback signals are benefits of this approach. The main drawback of the scalar technique is that the torque of IM cannot be precisely controlled [2]. The most prevalent VC approach is field-oriented control (FOC) [3-6]. In the FOC approach, the stator current space vectors are divided into two perpendicular parts,  $i_{sx}$  and  $i_{sy}$ . So, the torque and rotor flux can be individually controlled, just like the controllers of separated excited DC motors [7], [8]. The FOC strategy's drawback is that the IM mathematical model-based control method is more difficult than scalar control methods. However, it is possible to precisely adjust the torque and speed of IM at the same time [9-12]. As a result, the FOC approach is used in industrial settings for sophisticated control applications [13-15]. In this paper, the control model will base on the FOC technique. In order to implement the FOC strategy in an IM drive system, the controller needs to receive the feedback signals from sensors such as rotor speed, stator currents, voltage, etc. Obviously, the feedback signals from the sensors are necessary for the proper work of the modern controlled IM drive system. Especially, the feedback stator currents play a critical role in all the control algorithms.

This article suggests a field-oriented control technique for IM drive system speed control. Simulations in MATLAB/Simulink will be used to explain the great performance of the suggested strategy.

## 2. THE HYSTERESIS CURRENT CONTROLLER-BASED FIELD-ORIENTED CONTROL TECHNIQUE

Field Oriented Control (FOC), a typical control method used in IM drive systems, separately controls the flux and torque. The stator current space vector is divided into two perpendicular parts,  $i_{sx}$  and  $i_{sy}$ , in the rotating reference frame  $[x,y]$  that corresponds to the rotor flux space vector orientation to the x-axis, as illustrated in Figure 1. In this method, the component  $i_{sx}$  is controlled to maintain the amplitude of the flux rotor at the desired level. As a consequence, we may modify the torque in a linear connection by employing the component  $i_{sy}$  [3].

Space Vector Pulse Width Modulation (SVPWM) and Hysteresis Pulse Width Modulation are the two primary FOC approaches (HPWM). A space voltage vector is used by the SVPWM technique to control inverter switching. The most common method is SVPWM, which can maintain a constant motor speed even under fluctuating load conditions. However, the SVPWM requires intricate calculations, and the transient duration of the control is excessive. The switching of the inverter is managed by a current controller in the HPWM method. The current controller compares the phase current to the reference current before turning on the inverter. Hysteresis control is more user-friendly, quicker, and better suited to scenarios with unstable parameters, even if the HPWM's ripple is larger than the SVPWM's [13, 14]. In this article, the speeds of IM will be controlled using the HPWM technique.



**Fig. 1. Current space vector.**

Controlling the IM may be done using the FOC method, shown in Figure 2 [16]. The reference electrical torque may be calculated by utilizing a PI controller to calculate the difference between the reference speed and the actual speed. The following formula can then be used to identify the reference component:

$$i_{sy} = \frac{2}{3p} \cdot \frac{L_R}{L_m} \cdot \frac{T_e}{\psi_R} \quad (1)$$

The below equation can be used to determine the reference component from nominal rotor flux:

$$\psi_R = \frac{L_m}{1 + T_R} i_{sx} \quad (2)$$

The measured stator current data from sensors might also be transformed using the Clarke-Park transformation into a rotating coordinate system  $[x,y]$  as follows:

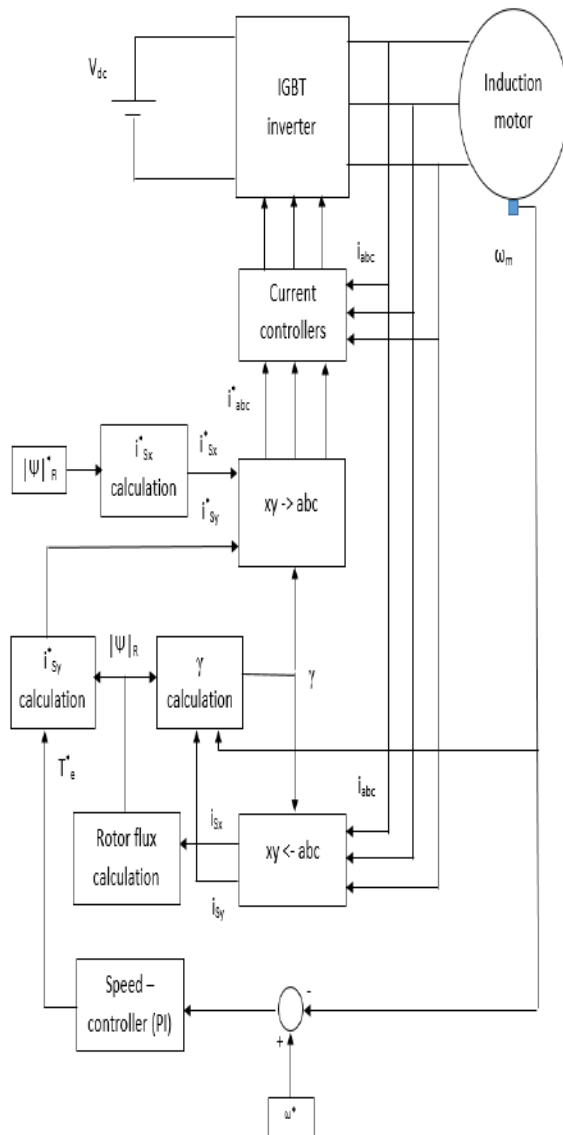
$$\begin{bmatrix} i_{sx} \\ i_{sy} \end{bmatrix} = \frac{2}{3} \begin{bmatrix} \cos(\gamma) & \cos(\gamma-120^\circ) & \cos(\gamma+120^\circ) \\ -\sin(\gamma) & -\sin(\gamma-120^\circ) & -\sin(\gamma+120^\circ) \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} \quad (3)$$

The feedback rotor speed of the speed sensor and the rotor slip may just be combined to approximate the component rotor flux angle in the following states:

$$\gamma = \int (p \cdot \omega_m + \omega_{sl}) dt \quad (4)$$

where:  $\omega_{sl} = \frac{i_{sy}}{T_R \psi_R}$

The values of the actual currents will be contrasted with the reference currents. The switching commands for the inverter are then created using these faults to generate the desired rotor speed.



**Fig. 2. Block diagram of the FOC [16].**

### 3. SIMULATION RESULTS

This part presents the simulation of the FOC method with feedback current signals from sensor for speed control of IM drive based on hysteresis current controller in MATLAB/SIMULINK. The simulation parameters of IMs are listed as:

$$P = 2.2 \text{ kW}, p = 2, U = 380 \text{ V},$$

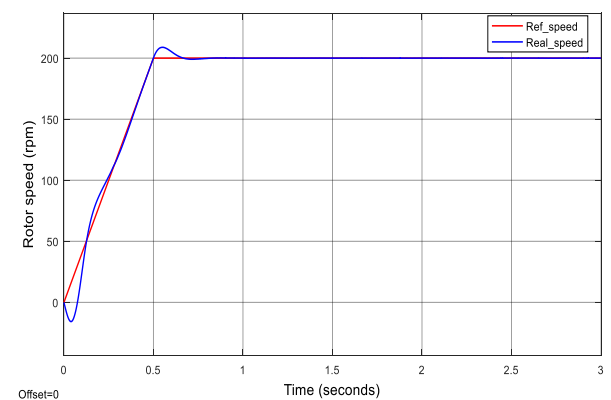
$$R_S = 3.179 \text{ } \Omega, R_R = 2.118 \text{ } \Omega,$$

$$L_S = 0.209 \text{ H}, L_R = 0.209 \text{ H}, L_m = 0.192 \text{ H}$$

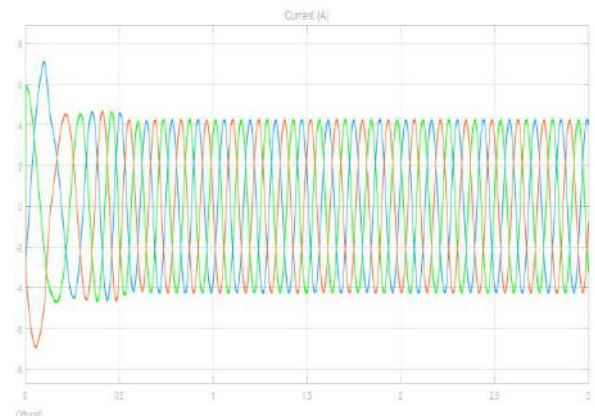
**Case 1:  $\omega_1 = 200 \text{ rpm}$  with  $T_{Load} = 3\text{N}$ :**

In the first case, the IM has been operated at the speed of 200rpm and torque load at 3N.

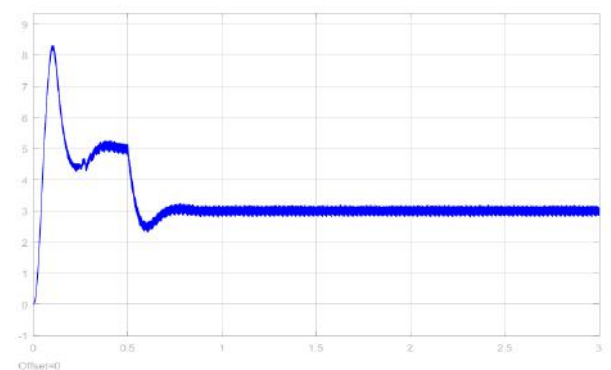
Figures 3 and 4 describe IM's reference, actual speed, and anticipated stator current for a 200rpm speed and a 3N load torque. Figure 5 shows the electrical torque of the IM. During the first period, we see a slight overshoot. But over a short period, the real speed slightly surpasses the reference speed. After then, the real IM speed is maintained at the reference speeds with a few tiny deviations.



**Fig. 3. Rotor speed at 200rpm and load torque 3N.**



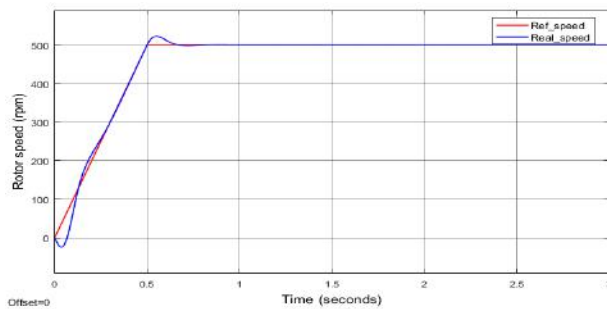
**Fig. 4. Current (A) at 200rpm and load torque 3N.**



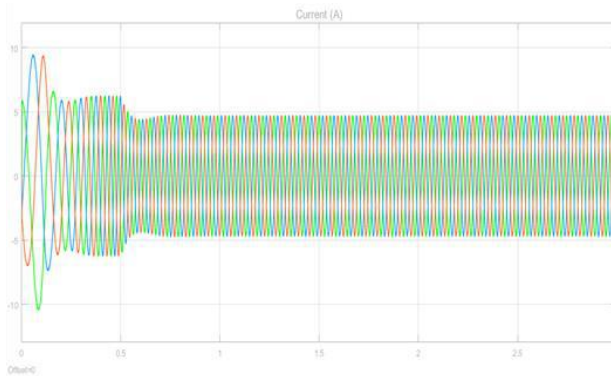
**Fig. 5. Te at 200rpm and load torque 3N.**

**Case 2:  $\omega_2 = 500$  rpm with  $T_{Load} = 5N$ :**

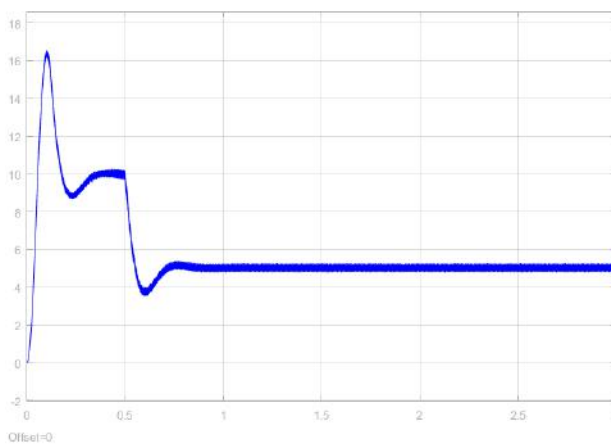
In the second case, the IM has been operated at the speed of 500 rpm, and the load torque is 5(N). Figures 6, 7, and 8 depict the performance of the current method in the FOC of IM drive systems. Figures 6 and 7 show this method's good control capability even when the speed and load are increased. Figure 8 shows the electrical torque of the IM. The rotor speed and phases still reach the reference speed in a short time.



**Fig. 6. Rotor speed at 500rpm and load torque 5N**



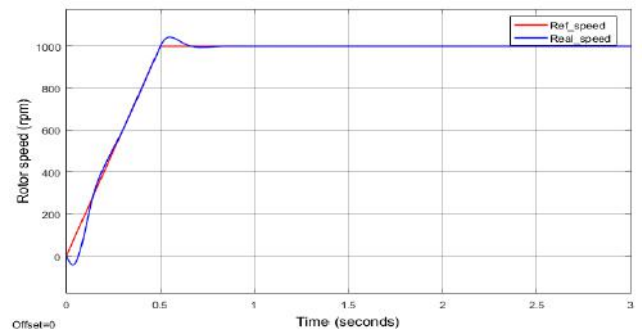
**Fig. 7. Current (A) at 500 rpm and load torque 5N.**



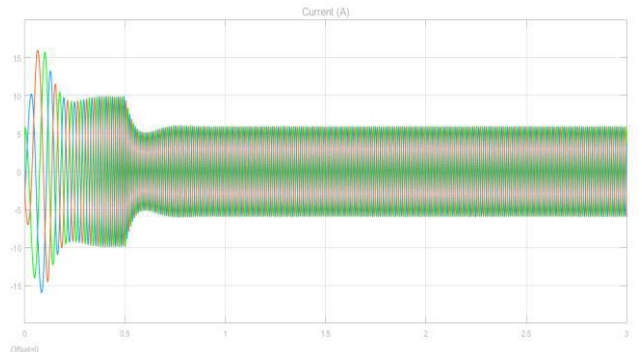
**Fig. 8. Te at 500 rpm and load torque 5N.**

**Case 3:  $\omega_1 = 1000$  rpm with  $T_{Load} = 10N$ :**

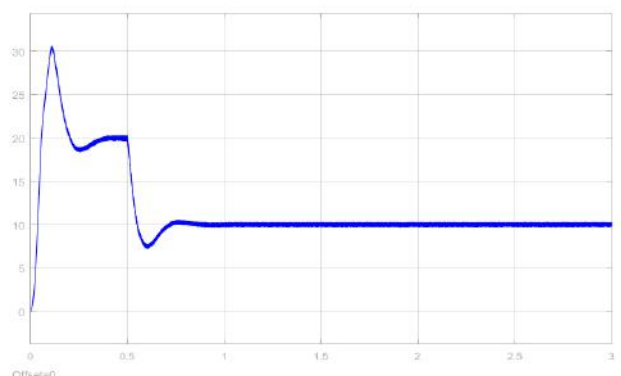
In this final case, we run the IM with a speed of 1000 rpm and a load torque of 10 N. The result of this case shows that the method is still reliable when running at low speed and high speed with different load torque. Figures 9, 10, and 11 display the result of the case 3 test at a speed of 1000 rpm, with a load torque of 10 N. These findings demonstrate the stability and dependability of the hysteresis current control FOC under a variety of speed and torque requirements.



**Fig. 9. Rotor speed at 1000rpm - load torque 10 N**



**Fig. 10. Current (A) at 1000 rpm - load torque 10 N.**



**Fig. 11. Current (A) at 1000 rpm - load torque 10 N.**

#### 4. CONCLUSIONS

The field-oriented control in the IM drive speed control was discussed in the study. The outstanding performance of the FOC approach has been demonstrated in numerous operational conditions. The simulation results show the efficiency of the suggested strategy to sustain the speed of IM drive systems in both loaded and unloaded operations.

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