ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization) Vol.2, Special Issue 1, March 2014

Proceedings of International Conference On Global Innovations In Computing Technology (ICGICT'14)

Organized by

Department of CSE, JayShriram Group of Institutions, Tirupur, Tamilnadu, India on 6th & 7th March 2014

Development Of Efficiency Model Of Three Phase Induction Machine And Improving Efficiency At Low Load Condition Using Controllers

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ABSTRACT: In this paper, presents a new approach that minimizes copper and iron losses and optimizes the efficiency of a induction motor drives. This method is based on a simple induction motor indirect field oriented control model includes various losses uses only conventional IM parameters. The efficiency maximization can be obtained by design PID controller. The proposed methods of computing Proportional, Integral and Derivative (PID) parameters controller for indirect vector control of induction motor. To calculate the PID parameter for each loop control and it can improve the efficiency of the three phase induction motor. Simulation results show robustness of the proposed method to system parameters variations.

KEYWORDS: PID, Indirect Field oriented control of induction motor.

I. INTRODUCTION

The utility of induction motor is more than 50% in the electrical energy generation worldwide. A small improvement in efficiency would significantly save the total electrical energy. Hence, it is important to optimize the efficiency of motor drive systems if significant energy savings are to be obtained. The induction motor (IM), especially the squirrel-cage type, is widely used in electrical drives and is responsible for most of the energy consumed by electric motors. The main objective of the project is to develop the mathematical model of an Induction Motor for calculating the efficiency. Usually, in vector control of AC machines, the field-oriented vector control of induction motor requires the speed control, torque control and flux control loop.In vector control, the control scheme is performed in a synchronously rotating reference frame. The stator currents are transformed into direct axis component (flux component), and quadrature component (Torque component). These vectors which are stationary in space are orthogonal or decoupled in nature.Usually achieved by decoupling the direct current-component and quadrature-component of induction motor. In order to design a control algorithm for induction motor, model of Induction motor is usually transform into two-axis frame. The Control system of the induction motor can be represented with speed loop,flux control,torque control loops.

These control loops required the computation of Proportional, Integral (PI)control parameters to be selected such that current, flux, and speed. Usually the PI parameters are chosen arbitrary or by trail and error method to achieved the desired system performance. Proportional gain to vary the bandwidth to meet the settling time specification. Derivative gain adjustments vary the system response to meet overshoot requirements. Increasing derivative gain will reduce the control signal magnitude. when the error rate is high, to eliminating overshoot. Integral gain is used to reduce steady state error caused by friction, gravity. Usually, induction motor control its convenient to design the control system base on synchronous frame. The AC induction is most of industrial and residential motor application.AC induction are design to operate at a constant input voltage and frequency and possible to effectively vary input frequency of the motor via Pulse Width Modulation (PWM) Techniques.

II. INDUCTION MOTOR MODEL

The induction motor, which is the most widely used motor type in the industry, has been favoured because of its good self starting capability ,simple and rugged structure, low cost and reliability. A three phase induction motor is a singly excited AC machine in the sense that it is supplied power from a single AC source .its stator winding is directly connected to AC source Where as its rotor winding receives its energy from stator by means of induction. The two MMF waves generated that are stator MMF and and rotor MMF both rotate in air gap in same direction at synchronous speed. These two MMF wave combine to give the resultant airgap flux density wave of constant amplitude and rotating at synchronous speed.

The model of squirrel cage induction motor in the rotating synchronous frame is given

$$\frac{di_{ds}}{dt} = -\frac{L_m{}^2 R_r + L_r^2 R_S}{\sigma L_s L_r^2} i_{ds} + \frac{L_m R_r}{\sigma L_s L_r^2}\psi_{dr} + \frac{L_m \omega_r}{\sigma L_s L_r}\psi_{dr} + \frac{V_{ds}}{\sigma L_s}$$

$$\frac{di_{qs}}{dt} = -\frac{L_m{}^2 R_r + L_r^2 R_S}{\sigma L_s L_r^2} i_{qs} + \frac{L_m R_r}{\sigma L_s L_r^2}\psi_{dr} + \frac{L_m \omega_r}{\sigma L_s L_r}\psi_{dr} + \frac{V_{qs}}{\sigma L_s}$$

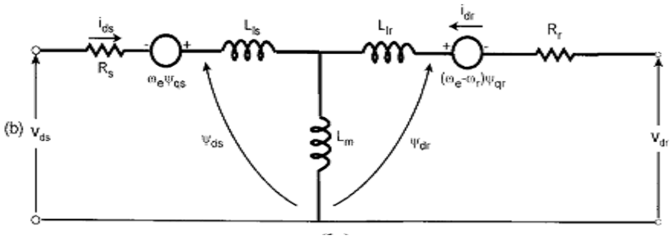
$$\frac{d\psi_{dr}}{dt} = \frac{L_m R_r}{L_r} i_{ds} - \frac{R_r}{L_r}\psi_{dr} - \frac{p}{2}\psi_{qr}\omega_r$$

The torque developed induction motor is given

$$T_e = \left(i_{qss} * \psi_{ds} - i_{dss} * \psi_{qr}\right)\left(\frac{3}{4} * p * \frac{L_m}{L_r}\right)$$

here

R_s, R_r	Stator and rotor resistance respectively
$L_s, L_{r,} L_m$	Stator rotor and mutual inductance
$\lambda_{ds,} \lambda_{qs}$	Stator d-axis and q-axis fluxes
$i_{ds,} i_{qs}$	Stator d-axis and q-axis current
$i_{dr,} i_{qr}$	Rotor d-axis and q-axis current
$\omega - \omega_r$	Reference frame and rotor electrical angular speed
J, B	Motor inertia and biscus friction coefficient
T_d, T_L, P	Developed torque,load torque and number of poles



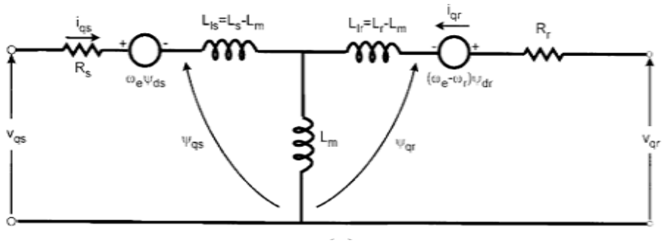


Figure 1. Induction motor model in synchronous frame

III. OPTIMAL PID PARAMETERS COMPUTATION METHOD

Looking at the mechanical model equation of the motor equation, it is clear that this equation is a first order system. Transforming equation into s-domain, yield the first system of the form

$$\omega_r(s) = \frac{K_m}{\tau_m s + 1}(T_d - T_L)$$

Where the mechanical time constant

$$K_m = \frac{p}{2B} \qquad \tau_m = \frac{J}{B}$$

The equation has a settling time of about $5\tau_m$. The characteristic equation of the closed-loop system shown in figure is given by

$$\frac{\omega_r}{\omega_r^*} = \frac{K_m K_p S + K_m K_i}{\tau_m s^2 + (1 + K_m K_p)s + K_m K_i}$$

The equation can be written as function of the required settling time as follows

$$K_p = \frac{5\tau_m}{K_m \tau_c}$$

$$K_i = \frac{5}{K_m \tau_c}$$

Where τ_s is a settling time of the closed loop system.

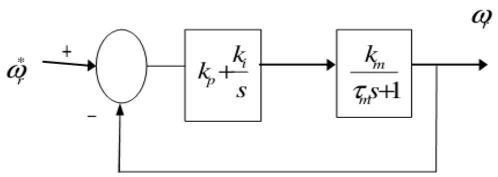


Figure 2 Speed control loop

IV. THE FIELD ORIENTATION PRINCIPLE

The field orientation concept implies that the current components supplied to the machine should be indirect field oriented in such a manner as to isolate the component of stator current magnetizing the machine (flux component) from the torque producing component. This can be accomplished by choosing the reference frame speed to be the instantaneous speed of the rotor flux linkage vector and Locking its phase such that the rotor flux is entirely in the d–axis (magnetizing axis), resulting in the mathematical constraint.

$$\lambda_{qr} = 0$$

The rotor flux indirect vector control is the most popular and widely used. It consists of aligning the d-axis and q axis of the reference frame with the rotor space vector. Since the control is performed in synchronously rotating reference frame the control parameters are transformed to synchronously rotating reference frame using unit vectors. Here unit vector signals are generated in a feed forward manner. Here flux orientation is achieved by imposing a slip frequency derived from the rotor dynamic equations so as to ensure flux orientation. For reference speed, the slip speed will be calculated. It will be added with the actual speed, which gives the synchronous speed of the rotor flux. From synchronous speed the position of the rotor flux is calculated.

$$\theta(t) = \int_0^t (\omega_{slp} + \omega_r)\, dt = \int_0^t \omega\, dt$$

V. SINUSOIDAL PWM

The sinusoidal PWM technique is very popular for industrial converters, in this isosceles triangle carrier wave of frequency f_r is compared with fundamental frequency f sinusoidal modulating wave, and the point of intersection determine the switching points of power devices. The notches and pulse widths of r_{ao} waveform vary in a sinusoidal manner so that the average or fundamental component frequency is the same as the f and its amplitude is proportional the command modulating voltage. The same carrier wave can be used for all the three phases. The input and output signals undergoing Pulse width modulation are shown in figure 4.

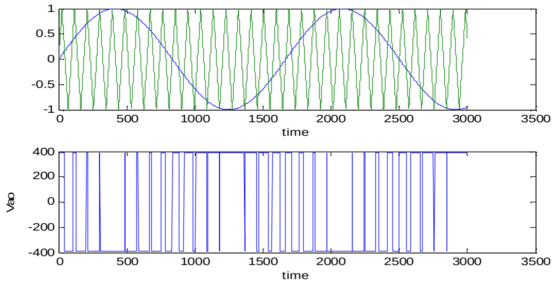


Figure 3 Sinusoidal PWM

VI. RESULT DISCUSSIONS

The performance of the proposed controller were investigated and the desired speed of 150 rad/sec. As it is clear from the resulted motor speed (Figure (4)) that the motor speed converge to desired speed without overshoot. It is also clear from figure (4).The stator direct axis and quadrature axis current waveform of induction motor as shown in figure (4).

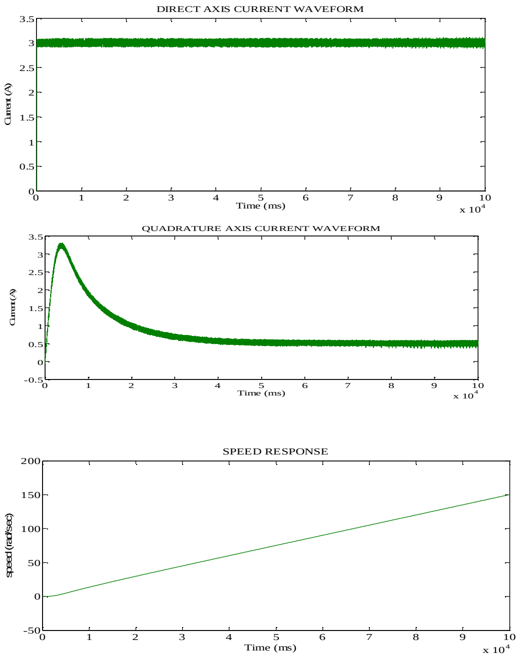


Figure 4 d-axis and q-axis current waveform and speed waveform

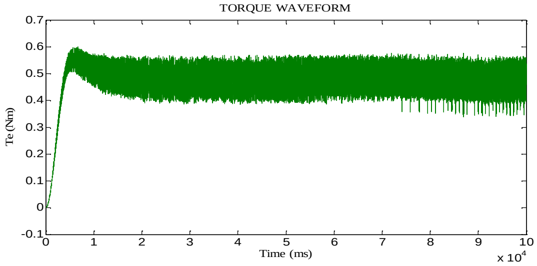
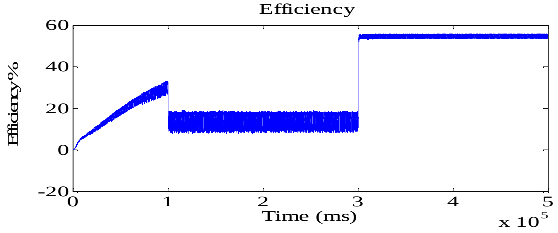


Figure 5 Torque waveform



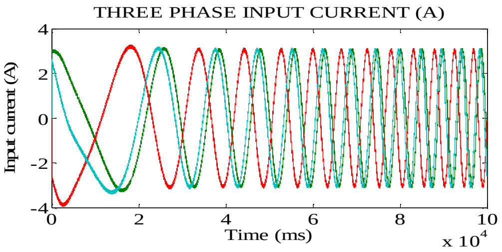


Figure 6 Efficiency and three phase input current of Induction Motor

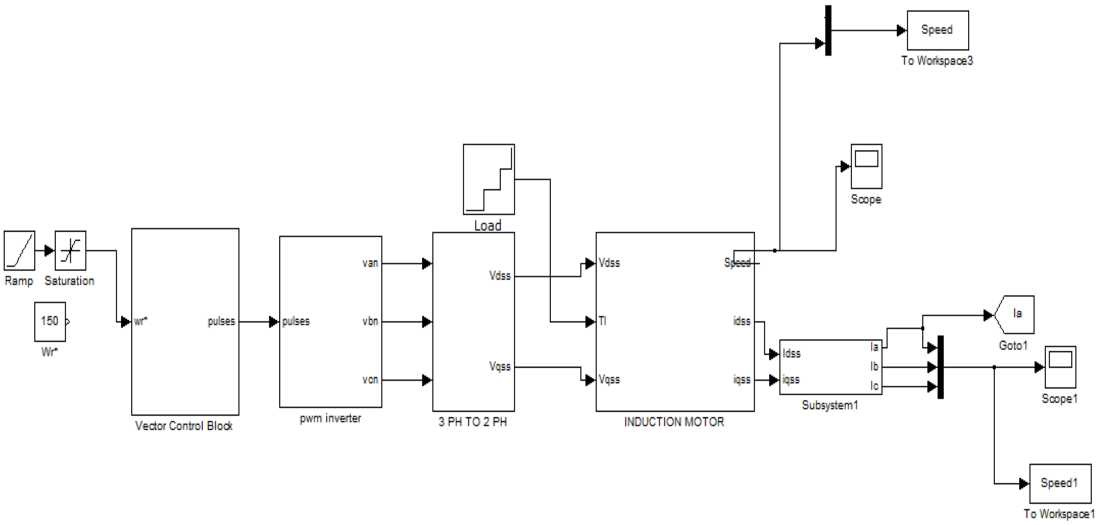


Figure 7.Indirect field oriented control system

VII. CONCLUSION

In this study we proposed mathematical modeling of three phase induction motor. The simulation results obtained shows good dynamic performance of the PID controller during transient period and sudden load changes. This system can be extended with other advanced soft computing techniques. From the presented study, one can conclude that, IM efficiency improvement strategy, implemented by PID controller.

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