International Journal of
Scientific Engineering and Technology Research
www.ijsetr.com

ISSN 2319-8885
Vol.07,Issue.03,
March-2018,
Pages:0361-0364

Speed Control of Induction Motors using PI Controllers

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Abstract: The classical approach of designing speed controllers for vector control of an induction motor have undergoes many problems like instability, rise time, settling time etc.., during load disturbances. In this paper, hybrid controller is designed for a 3 phase 50 HP, cage type induction motor through MATLAB/SIMULINK to decrease rise time, settling time etc. According to the simulation self tuning of PI controller performs well and gives better response when compared with classical pi controller.

Keywords: Induction Motor, Vector Control, Classical PI Controller.

I. INTRODUCTION

An induction motor is an asynchronous AC (alternating current) motor. Induction motors plays a vital role in industrial appliances like control and automation, 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.. hence, they are often called the workhorse of the motion industry. Its main features are robustness, relatively low cost, reliability and efficiency. So, Induction motors have significant importance and used more in the industrial variable speed drive system with the development of the field oriented control technology. Induction motor behaves like a separately excited DC motor using vector control technology. In classical FOC, a PI controller is designed to control the speed of the induction motor drive. It induces many problems like more rise time, settling time, overshoot, under shoot, steady state error etc., oscillation of speed and torque due to sudden changes in load and external disturbances [1]. This behaviour reduces the performance of motor. A PI controller with high accuracy and efficiency. The fuzzy logic controller will give a poor response for load transients and speed command variations[3]. But it will not give a good response during changes in load demand.

II. INDUCTION MOTOR MODELLING

The indirect vector control method is essentially the same as direct vector control, except the unit vector signals ($\cos\theta_e$ and $\sin\theta_e$) are generated in feed forward manner using the measured rotor speed ω_r and the slip speed ω_{sl}. Indirect vector control is widely used in industrial applications. The induction machine d-q or dynamic equivalent circuit is shown in Fig.1.

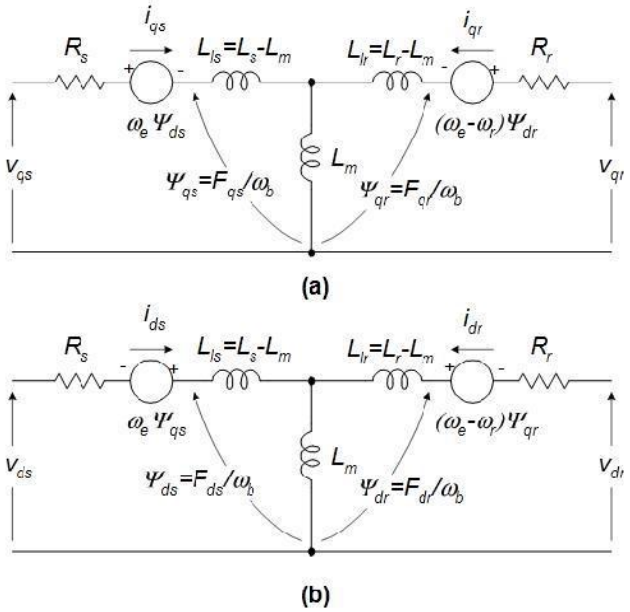

Fig.1. dynamic or d-q equivalent circuit of an induction motor.

Fig.1 dynamic or d-q equivalent circuit of an induction motor.

Where
d: direct axis,
q: quadrature axis,
s: stator variable,
r: rotor variable,
V_{qs}, V_{ds}: q & d axis stator voltages,
V_{dr}, V_{qr}: q & d axis rotor voltages,
F_{mq} , F_{md}: q & d axis magnetizing flux linkages
R_r : rotor resistance,
R_s: stator resistance,
X_{ls}: stator leakage reactance (ωL_{ls}),
Xlr: rotor leakage reactance (ωL_{lr}).

The mathematical model of induction motor is given by

$$\theta_e = \int \omega_e \, dt$$

In this paper stationary reference frame is used for designing the motor. so three-phase (as-bs-cs) variables transformed into two-phase stationary reference frame(d^s-q^s) variables.

$$\begin{bmatrix}V_{ds}\\ V_{qs}\end{bmatrix} = \frac{2}{3}\begin{bmatrix}1 & -0.5 & -0.5\\ 0 & -0.866 & 0.866\end{bmatrix}\begin{bmatrix}V_a\\ V_b\\ V_c\end{bmatrix}$$

By using fig.1, the electrical system equations can be written as follows:

$$V_{ds} = R_s i_{ds} + \frac{d\Psi_{ds}}{dt} - \omega_e \psi_{qs} \quad (1)$$

$$V_{qs} = R_s i_{qs} + \frac{d\Psi_{qs}}{dt} + \omega_e \psi_{ds} \quad (2)$$

$$V_{qr} = R_r i_{qr} + \frac{d\Psi_{qr}}{dt} + (\omega_e - \omega_r)\psi_{dr} \quad (3)$$

$$V_{dr} = R_r i_{dr} + \frac{d\Psi_{dr}}{dt} - (\omega_e - \omega_r)\psi_{qr} \quad (4)$$

$$\Psi_{qs} = L_s i_{qs} + L_m i_{qr} \quad (5)$$

$$\Psi_{qr} = L_r i_{qr} + L_m i_{qs} \quad (6)$$

$$\Psi_{ds} = L_s i_{ds} + L_m i_{dr} \quad (7)$$

$$\Psi_{dr} = L_s i_{dr} + L_m i_{ds} \quad (8)$$

Where $L_s = L_{ls} + L_m$, $L_r = L_{lr} + L_m$ L_{ls} and L_{lr} are self inductances of stator and rotor respectively. L_m is mutual inductance of stator and rotor. Rotor circuit equations are

$$\frac{d\psi_{qr}}{dt} + \frac{R_r}{L_r}\psi_{qr} - \frac{L_m}{L_r}R_r i_{ds} - \omega_{sl}\psi_{dr} \quad (9)$$

$$\frac{d\psi_{dr}}{dt} + \frac{R_r}{L_r}\psi_{dr} - \frac{L_m}{L_r}R_r i_{qs} - \omega_{sl}\psi_{qr} \quad (10)$$

For singly fed machines, such as a cage rotor $V_{qr} = V_{dr} = 0$. For stationary referene frame and decoupling control $\omega_e = 0$. So the stator flux component of current i_{ds} coincides with d^e axis and torque component of current i_{qs} coincides with q^e axis. Consequently $\Psi_{qr} = 0$ and $\Psi_{dr} = \psi_r$.

$$\frac{d\Psi_{dr}}{dt} = 0 \quad (11)$$

Based on the above equations, the torque and rotor speed can be determined as follows:

$$T_e = \frac{3}{2}\frac{p}{2}\frac{1}{\omega_b}(\psi_{ds} i_{qs} - \psi_{qs} i_{ds})$$

$$\omega_r = \int \frac{P}{2J}(T_e - T_L)$$

The inputs of a squirrel cage induction machine are the three phase voltages, their fundamental frequency, and the load torque. The outputs, on the other hand, are the three phase currents, the electrical torque, and the rotor speed. The d-q model requires that all the three-phase variables be transformed to the two–phase stationary reference frame. Consequently, the induction machine model will have blocks transforming the three-phase voltages to the d-q frame and the d-q currents back to three-phase The induction machine model implemented in this paper is shown in Fig.2. It consists of five major blocks: the o-n conversion, abc-dq conversion, dq-abc conversion, unit vector calculation, and induction machine d-q model blocks as shown in Figs3 and 4.

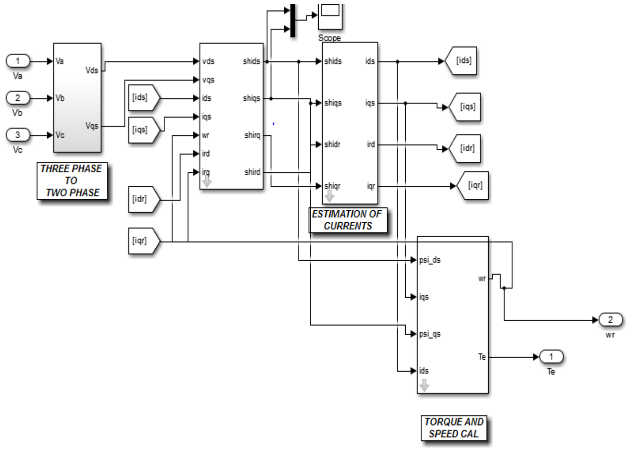

Fig.2. Subsystem for motor model.

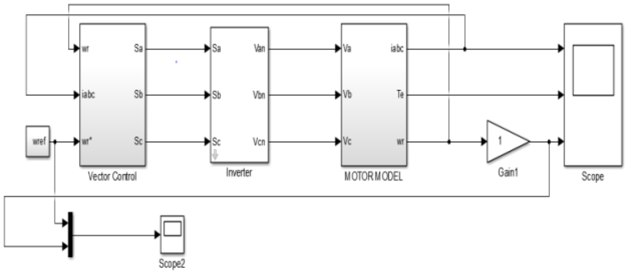

Fig.3 The developed simulink model for speed control of an induction motor.

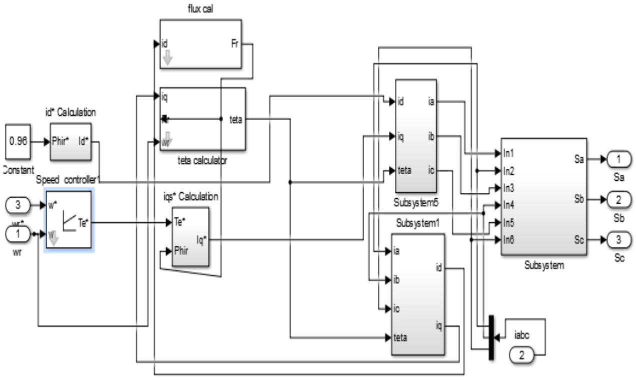

Fig.4. Subsystem for indirect vector control.

III. CONTROLLERS

A. PI Controller

Control signal used for this technique is given by

$$T = Kp\, e + Ki \int e\, dt \quad (12)$$

The proportional controller is a device produces an output signal which is proportional to the input signal. It improves the steady state response, disturbance signal rejection and relative stability. It also decreases the sensitivity of the system w.r.t parameters. The PI controller produces an output signal consisting of two terms- one proportional to input signal and the other proportional to the integral of input signal. If the gains of the controller exceed a certain value, the variations in the command torque become too high and will decrese stability of the system as shown in Fig.6. To overcome this problem, a limiter ahead of the PI controller is used. Block diagram of speed control of an induction motor with PI controller is shown in fig.7.

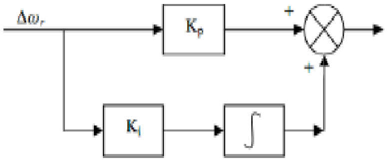

Fig.5. PI Controller.

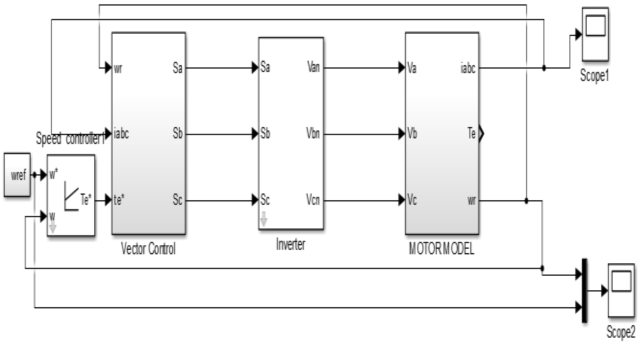

Fig.6. simulink model for speed control of an induction motor with pi controller.

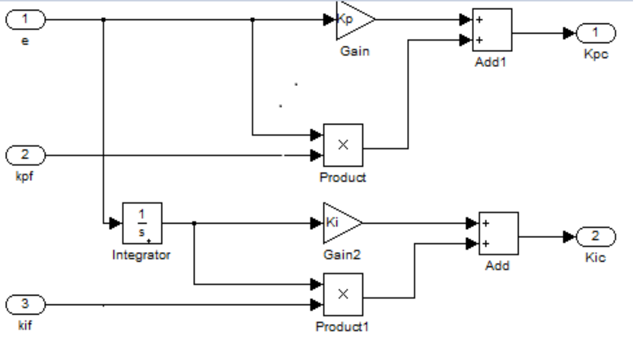

Fig.7. flow diagram of self tuning pi controller.

IV. SIMULATION RESULTS

A complete mathematical model of FOC induction motor with a 50 HP (37KW) is simulated in MATLAB-SIMULINK. The Induction motor used in this is a 50 HP, 460V, four-pole, 60Hz motor having the following parameters:

TABLE I: Parameters

Rated power	50 HP
Voltage	460v
Stator resistance	0.087
Rotor resistance	0.228
Stator inductance	0.17
Rotor indutance	0.17
Mutual inductance	0.165
Moment of inertia	0.089

The machine is initially running at 100rad/sec with no load. The reference speed is linearly increased from 100 to 120 rad/sec at 0.1sec and load applied at 0.5 sec with load torque T_l = 10Nm. At 0.7 sec load was removed. At 1.5sec braking was applied with T_l=-10nm.simulation were carried out with PI controller the indirect vector control of induction motor on various system disturbances shown in figs. 8 and 9 respectively.

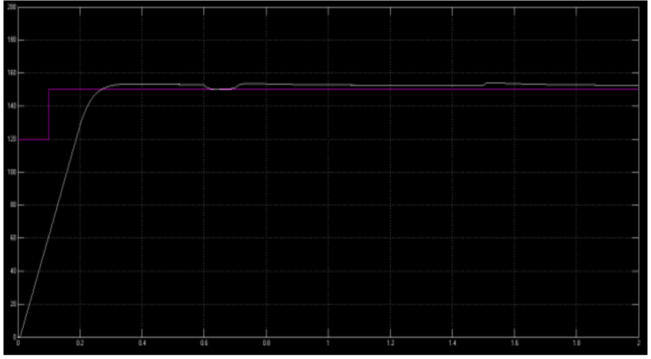

Fig.8. Forward motoring with load changes of an induction motor using conventional pi controller.

Fig.9. torque response with PI controller.

Table 2 shows the comparison results of PI in terms of rise time, Settling time, overshoot and steady state value. By observing figs.8 and 9 Good torque response is obtained with pi controller at all the instants. Less oscillation occurred in the torque response with PI Controller.

TABLE II: Time Domain Specifications

specifications	PI
Rise time	0.17
Maximum peak overshoot	153.3
Steady state value	152.5
Settling time	0.46

V. CONCLUSION

The performance of the self-tuning PI for the indirect vector control PWM voltage fed induction motor drive has been simulated and compared with that of conventional PI controller’s performance. PI controller was simulated for various load condition. The simulation results show that the designed PI controller realizes a good dynamic behavior of the motor to sudden changes with a less rise time, less overshoot and less steady state value. So it has a better performance and Good torque response is obtained with self tuning of PI.

VI. REFERENCES

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