International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878, Volume-1, Issue-5, November 2012

Sensorless Speed Control of Induction Motor Using MRAS

G. Pydiraju, M. Daivaasirvadam

Abstract : ***In order to implement the vector control technique, the motor speed information is required. Tachogenerators, resolvers or incremental encoders are used to detect the speed. These sensors require careful mounting and alignment and special attention is required with electrical noises. Speed sensor needs additional space for mounting and maintenance and hence increases the cost and the size of the drive system .These problems are eliminated by speed sensorless vector control by using model reference adaptive system. Model reference adaptive system is a speed estimation method having two models namely reference and adaptive model .The error between two models estimates induction motor speed. This project proposes a Model Reference Adaptive System (MRAS) for estimation of speed of induction motor. An Induction motor is developed in stationary reference frame and Space Vector Pulse Width Modulation (SVPWM) is used for inverter design. PI controllers are designed controlling purpose. It has good tracking and attains steady state response very quickly which is shown in simulation results by using MATLAB/SIMULINK.***

Keywords – Sensorless vector control, Model Reference Adaptive System (MRAS), Induction motor, stationary reference frame, Speed estimation.

I. INTRODUCTION

In recent years, the vector control theory has been receiving much attention because of the better steady and dynamic performance over conventional control methods in controlling motors torque and speed. In various vector control schemes, the speed sensorless vector control has been a relevant area of interest for many researchers due to its low drive cost, high reliability and easy maintenance. There are two main parameters which are required in speed sensorless vector control of induction motor, those are, the motor flux and speed estimation. These parameters are necessary for establishing the outer speed loop feedback and also in the flux and torque control algorithms. . In order to get good performance of sensorless vector control, different speed estimation methods have been proposed. Such as direct calculation method, model reference adaptive system (MRAS), Observers (extended Kalman filter, luenberger etc), Estimators using artificial intelligence etc .

Out of various speed estimation methods, MRAS-based speed sensorless estimation has been commonly used in AC speed regulation systems due to its good performance and ease of implementation.

Revised Manuscript Received on 30 November 2012.
* Correspondence Author

G. Pydiraju*, PG Student, E.E.E Dept., Vignan's Institute Of Information Technology, Visakhapatnam, Andhra Pradesh, India.

M. Daivaasirvadam, Assistant Professor,E.E.E Dept., Vignan's Institute Of Information Technology, Visakhapatnam, Andhra Pradesh, India.

In order to design MRAS for sensorless speed estimation, first we have to model the induction motor. In induction motor, inputs to motor are stator currents and voltages and output is rotor speed. That's why while choosing reference model for MRAS, we have to form rotor flux equation in the form of stator side parameters. In adaptive model, speed is the adaptive parameter.

II. MODELING OF INDUCTION MOTOR IN STATOR REFERENCE FRAME

Generally, an IM can be described uniquely in arbitrary rotating frame, stationary reference frame or synchronously rotating frame. The required transformation in voltages, currents, or flux linkages is derived in a generalized way. R.H. Park, in the 1920s, proposed a new theory of electrical machine analysis to represent the machine in d – q model.For transient studies of adjustable speed drives, it is usually more convenient to simulate an IM and its converter on a stationary reference frame. Moreover, calculations with stationary reference frame are less complex due to zero frame speed. The Equations of the induction motor in stationary reference frame can be represented by using flux linkages as variables. This involves the reduction of a number of variables in the dynamic equations. Even when the voltages and currents are discontinuous the flux linkages are continuous. The stator and rotor flux linkages in the stator reference frame are defined as

$$\left.\begin{aligned}\psi_{qs} &= L_s i_{qs} + L_m i_{qr}\\ \psi_{ds} &= L_s i_{ds} + L_m i_{dr}\\ \psi_{qr} &= L_r i_{qr} + L_m i_{qs}\\ \psi_{dr} &= L_r i_{dr} + L_m i_{ds}\end{aligned}\right\} \text{-------------- (1)}$$

2.17

$$\left.\begin{aligned}\psi_{qm} &= L_m (i_{qs} + i_{qr})\\ \psi_{dm} &= L_m (i_{ds} + i_{dr})\end{aligned}\right\} \text{-------------- (2)}$$

Stator and rotor voltage and current equations are as follows

$$\left.\begin{aligned}v_{ds} &= R_s i_{ds} + p\psi_{ds}\\ v_{qs} &= R_s i_{qs} + p\psi_{qs}\\ v_{dr} &= R_r i_{dr} + \omega_r \psi_{qr} + p\psi_{dr}\\ v_{qr} &= R_r i_{qr} - \omega_r \psi_{dr} + p\psi_{qr}\end{aligned}\right\} \text{-------------- (3)}$$

Since the rotor windings are short circuited, the rotor voltages are zero. Therefore

$$\left.\begin{aligned}R_r i_{dr} + \omega_r \psi_{qr} + p\psi_{dr} &= 0\\ R_r i_{qr} - \omega_r \psi_{dr} + p\psi_{qr} &= 0\end{aligned}\right\} \text{---------------- (4)}$$

From (5), we have

$$\left.\begin{aligned} i_{dr} &= \frac{-p\psi_{dr} - \omega_r \psi_{qr}}{R_r} \\ i_{qr} &= \frac{-p\psi_{qr} + \omega_r \psi_{dr}}{R_r} \end{aligned}\right\} \quad \text{--------------(5)}$$

By solving the equations (4)-(6) we get the following equations

$$\psi_{ds} = \int (v_{ds} - R_s i_{ds})dt \quad \text{---------------- (6)}$$

$$\psi_{qs} = \int (v_{qs} - R_s i_{qs})dt \quad \text{---------------- (7)}$$

$$\psi_{dr} = \frac{-L_r \omega_r \psi_{qr} + L_m i_{ds} R_r}{R_r + sL_r} \quad \text{------------------ (8)}$$

$$\psi_{qr} = \frac{L_r \omega_r \psi_{dr} + L_m R_r i_{qs}}{R_r + sL_r} \quad \text{------------------ (9)}$$

$$i_{ds} = \frac{v_{ds}}{R_s + sL_s} - \left[\frac{\psi_{dr}.sL_m}{L_r.(R_s + sL_s)} \right] \quad \text{------------- (10)}$$

$$i_{qs} = \frac{v_{qs}}{R_s + sL_s} - \left[\frac{\psi_{qr}.sL_m}{L_r.(R_s + sL_s)} \right] \quad \text{------------ (11)}$$

The electromagnetic torque of the induction motor in stator reference frame is given by

$$T_e = \frac{3}{2}\frac{p}{2} L_m (i_{qs} i_{dr} - i_{ds} i_{qr}) \quad \text{- ------------- (12)}$$

Or $T_e = \frac{3}{2}\frac{p}{2}\frac{L_m}{L_r}(i_{qs}\psi_{dr} - i_{ds}\psi_{qr})$ --------------(13)

III. SVPWM INVERTER

Processing of the torque status output and the flux status output is handled by the optimal switching logic. Fig (3) shows the schematic diagram of voltage source inverter. The function of the optimal switching logic is to select the appropriate stator voltage vector that will satisfy both the torque status output and the flux status output.

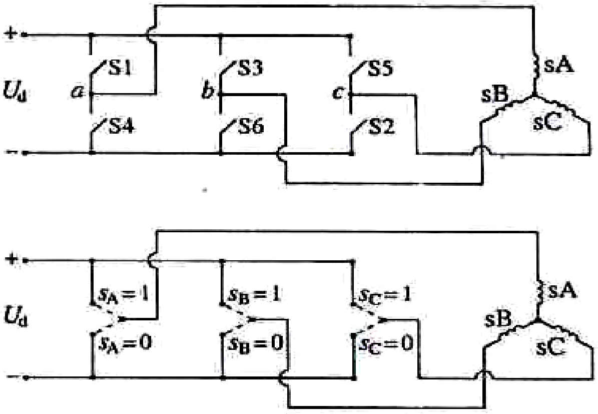
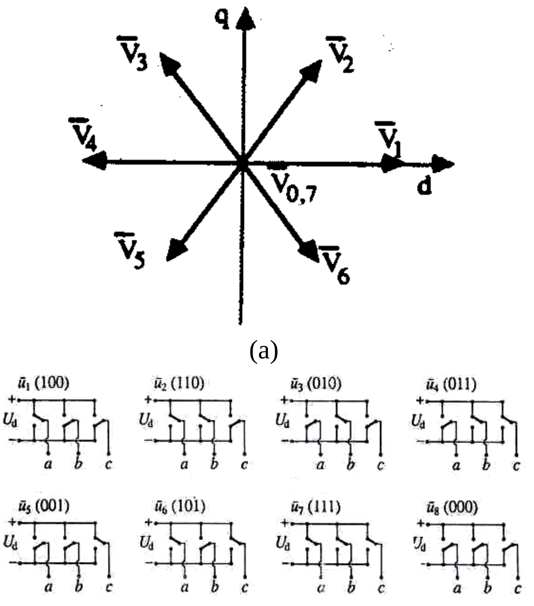


Fig 3: Schematic diagram of voltage source inverter In reality, there are only six nonzero voltage vectors and two zero voltage vectors as shown in Fig 3(a) & (b).



(a)

(b)

Fig: 3(a) Inverter Switching Stages, (b) Switching –voltage space vectors.

The machine voltages corresponding to the switching states can be calculated by using the following relations. motor line and phase voltages are

$$\left.\begin{aligned} v_{ab} &= v_a - v_b \\ v_{bc} &= v_b - v_c \\ v_{ca} &= v_c - v_a \end{aligned}\right\} \quad \text{--------------------- (14)}$$

$$\left.\begin{aligned} v_{as} &= \frac{v_{ab} - v_{ca}}{3} \\ v_{bs} &= \frac{v_{bc} - v_{ab}}{3} \\ v_{cs} &= \frac{v_{ca} - v_{bc}}{3} \end{aligned}\right\} \quad \text{----------------------- (15)}$$

IV. IRECT VECTOR CONTROL

The direct vector control depends on the generation of unit vector signals from rotor flux signals. The principle vector control parameters ids*, and iqs* , which are dc values in synchronously rotating frame, are converted to stationary frame with the help of a unit vectors cosθ$_e$ and sinθ$_e$ which are generated from flux vector signals .The resulting stationary frame signals are then converted to phase current commands for the inverter. The flux signals ψ_{dr}^{s} and ψ_{qr}^{s} are generated from the machine terminal voltages and currents. Basic block diagram of direct vector control shown in fig.4.

$$\Psi_{dr}^{\ s} = \hat{\Psi}_r \cos\theta_e \ , \ \Psi_{qr}^{\ s} = \hat{\Psi}_r \sin\theta_e$$

$$\cos\theta_e = \frac{\Psi_{dr}^{\ s}}{\hat{\Psi}_r} \ ; \ \sin\theta_e = \frac{\Psi_{qr}^{\ s}}{\hat{\Psi}_r}$$

Where vector $\overline{\Psi}_r$ is represented by magnitude $\hat{\Psi}_r$ the unit vector signals (cosθ$_e$ and sinθ$_e$), when used for vector rotation. The generation of a unit vector signal from feed back flux vectors gives the name “direct vector control.

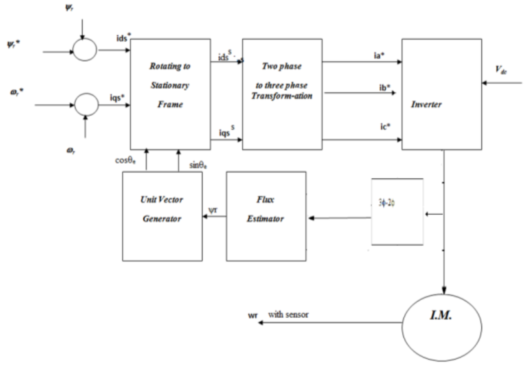


Fig 4. Basic block diagram of direct vector control

V. SENSORLESS VECTOR CONTROL

Sensor less vector control of induction motor drive essentially means vector control without any speed sensor. An incremental shaft mounted speed encoder, usually an optical type is required for closed loop speed or position control in both vector control and scalar controlled drives. Speed encoders undesirable in a drive because it adds cost and reliability problems, besides the need for a shaft extension and mounting arrangement.

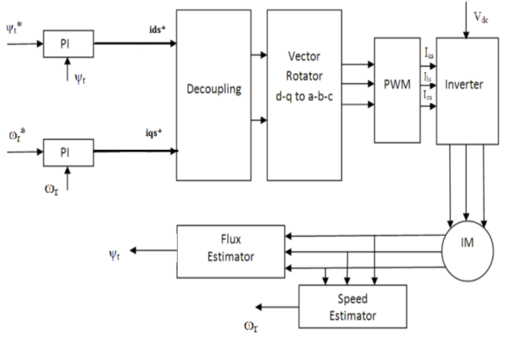


Fig 5:Block Diagram of Sensor less Control of Induction motor.

The schematic diagram of control strategy of induction motor with sensor less control is shown in Fig 5.. Sensor less control induction motor drive essentially means vector control without any speed sensor [5]. The inherent coupling of motor is eliminated by controlling the motor by vector control, like in the case of as a separately excited motor. The inverter provides switching pulses for the control of the motor. The flux and speed estimators are used to estimate the flux and speed respectively. These signals then compared with reference values and controlled by using the PI controller.

VI. MODEL REFERENCING ADAPTIVE SYSTEM (MRAS)

Mras is a speed estimation method. MRAS scheme which is less complex and more effective. The MRAS approach uses two models. The model that does not involve the quantity to be estimated (the rotor speed, ωr) is considered as the reference model. The model that has the quantity to be estimated involved is considered as the adaptive model (or adjustable model). The output of the adaptive model is compared with that of the reference model, and the difference is used to drive a suitable adaptive mechanism whose output is the quantity to be estimated (the rotor speed). The adaptive mechanism should be designed to assure the stability of the control system.

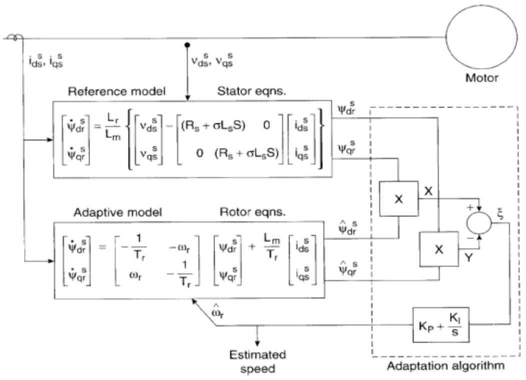


Fig 7: block diagram of mras

The basic block diagram of MRAS speed estimation system is shown in Fig 7. The model reference approach (MRAS) makes use of redundancy of two-machine model of different structures that estimate the same state variables. Both models are referred to in the stationary reference frame. where the output of a reference model is compared with the output of an adjustable or adaptive model until the errors between the two models vanish to zero . With the correct value of rotor speed, the fluxes determined from the two models should match. An adaptation algorithm with P-I control can be used to tune the speed value until the two flux values match.

Reference frame model flux equations are

$$\frac{d}{dt}\psi_{dr} = \frac{L_r}{L_m}\left[v_{ds} - (R_s + \sigma\ SL_s)i_{ds}\right]$$

$$\frac{d}{dt}\psi_{qr} = \frac{L_r}{L_m}\left[v_{qs} - (R_s + \sigma\ SL_s)i_{qs}\right]$$

Adaptive model flux equations are

$$\frac{d}{dt}\psi_{qr} = \frac{L_m}{T_r} i_{qs} + \omega_r \psi_{dr} + \frac{1}{T_r}\psi_{qr}$$

$$\frac{d}{dt}\psi_{dr} = \frac{L_m}{T_r} i_{ds} - \omega_r \psi_{qr} - \frac{1}{T_r}\psi_{dr}$$

Adaptive mechanism for speed

$$\omega_r = \varsigma\left(k_p + \frac{k_i}{s}\right)$$

$$\varsigma = A - B = \hat{\psi}_{dr}^s \psi_{qr}^s - \hat{\psi}_{qr}^s \psi_{dr}^s$$

VII. DIRECT VECTOR CONTROL OF INDUCTION MOTOR DRIVE

The Vector Control or Field orientation control of induction motor is simulated MATLAB SIMULINK. platform to study the various aspects of the controller. The actual system can be modeled with a high degree of accuracy in this package. It provides a user interactive platform and a wide variety of numerical algorithms. This chapter discusses the realization of vector control of induction motor using Simulink blocks.

Fig.8 shows the Vector controlled Induction Motor block simulink diagram for simulation.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

This system consisting of Induction Motor Model, Three Phase to Two phase transformation block, Two phase to Three phase block, Flux estimator block and Inverter block.

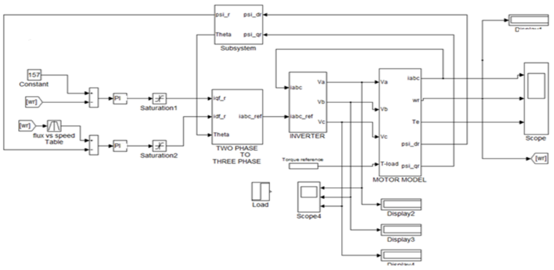


Fig 8: Simulink Model of Direct Vector Controlled Induction motor

A. Induction Motor Model

The motor is modeled in stator reference frame. The dynamic equations are given by (1) to (14). By using these equations we can develop the induction motor model in stator reference frame. Fig.9 shows the simulink block diagram for motor model. Inputs to this block are direct and quadrature axes voltages and load torque. The outputs are direct and quadrate axis rotor fluxes, direct and quadrature axes stator currents, electrical torque developed and rotor speed.

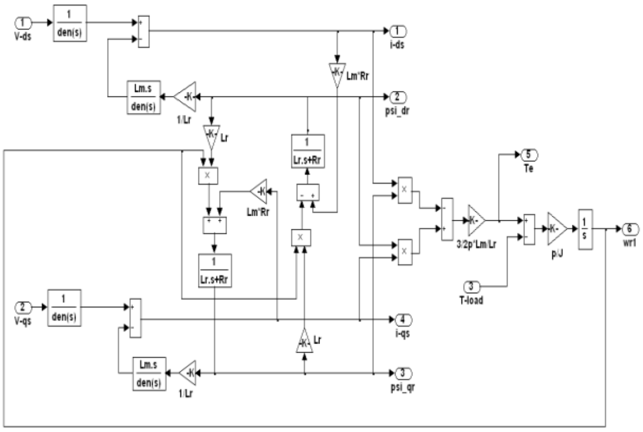


Fig.9: Simulink block diagram for induction motor model

B. Inverter

Fig 4 shows the Voltage Source Inverter (VSI), it consists of an Optimal Switching Logic which is shown in Fig 10. The function of the optimal switching logic is to select the appropriate stator voltage vector that will satisfy both the torque status output and the flux status output. Processing of the torque status output and the flux status output is handled by the optimal switching logic.

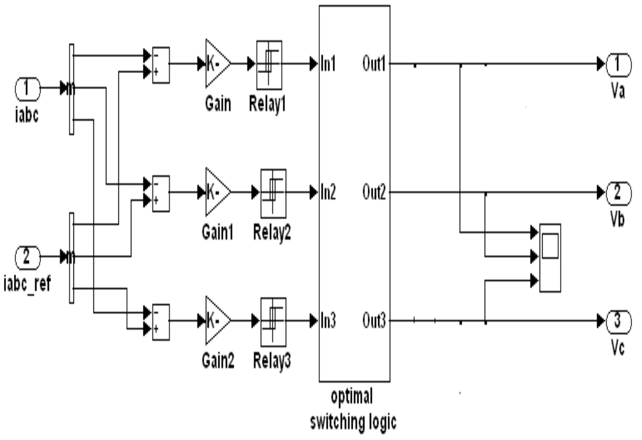


Fig 10: Voltage Source Inverter

C. Model Reference Adaptive System (MRAS)

Fig 11 shows the simulink block diagram Model Referencing Adaptive System (MRAS). Which is consists Two blocks one is called Reference Model and other is Adaptive Model. The voltage model's stator-side equations, (16) & (17) are defined as a Reference Model and the simulink block diagram of Reference Model is shown in Fig11. The Adaptive Model receives the machine stator voltage and current signals and calculates the rotor flux vector signals, as indicated by equations, (18) and (19) which is shown in Fig 11. By using suitable adaptive mechanism the speed ω_r, can be estimated and taken as feedback.

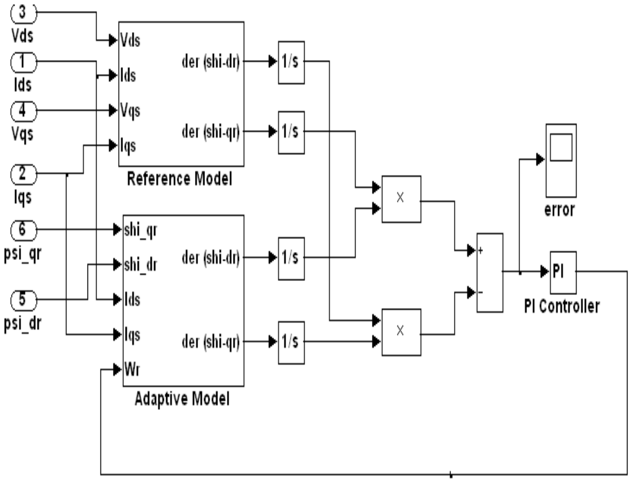


Fig 11: Simulink block diagram for Model Referencing Adaptive System

D. Sensor Less Control Of Induction Motor

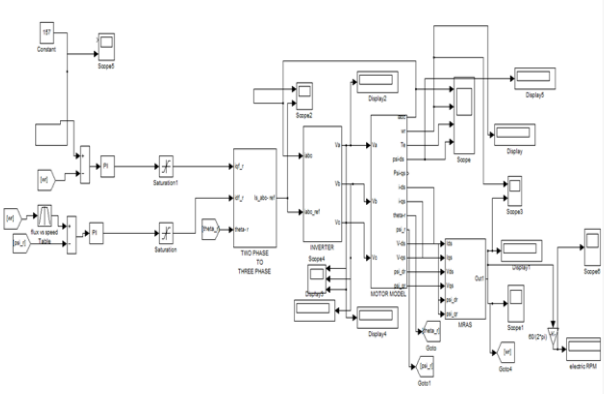


Fig 12: Simulink root block diagram of Sensorless control of induction motor using MRAS

The Sensor less control of induction motor using Model Reference Adaptive System (MRAS) is simulated on MATLAB/SIMULINK - platform to study the various aspects of the controller. The actual system can be modeled with a high degree of accuracy in this package. It provides a user interactive platform and a wide variety of numerical algorithms. Here we are going to discuss the realization of Sensor less control of induction motor using MRAS for simulink blocks. Fig. 12 shows the root-block simulink diagram for simulation. Main subsystems are the 3-phase to 2-phase transformation, 2-phase to 3-phase transformation, induction motor model, Model Reference Adaptive System (MRAS) and optimal switching logic & inverter.

VIII. SIMULATION RESULTS

The simulation of Vector Control of Induction Motor is done by using MATLAB®/SIMULINK. The results for different cases are given below.

(a) **Direct Vector control**: Reference speed = 100 rad/sec on no-load

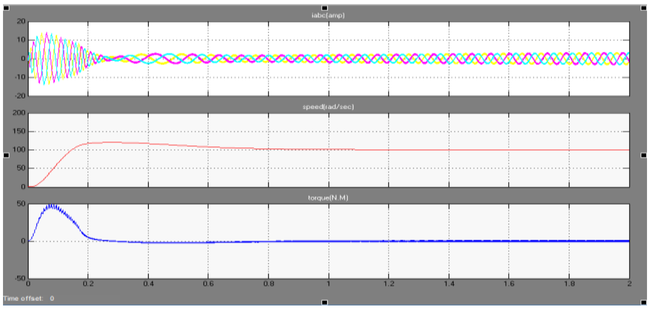


Fig 13: 3-ϕ currents, Speed, and Torque for no-load reference speed of 100 rad/sec

SENSORLESS SPEED CONTROL USING MRAS

a) under no load :**R**eference speed 100 rad/sec

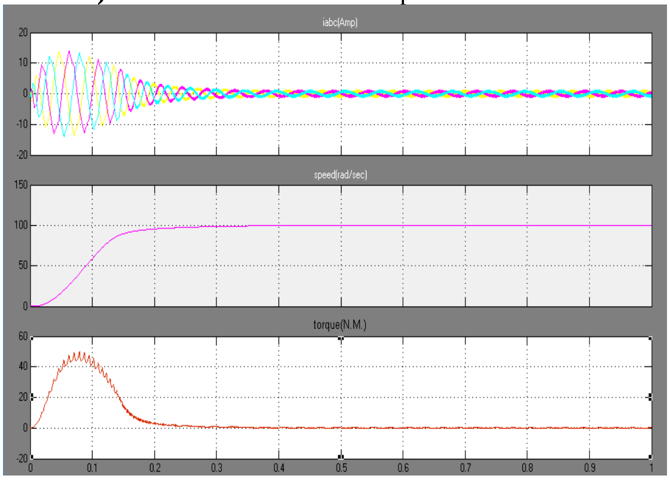


Fig 14:3-ϕ currents, Speed, and Torque for no-load reference speed of 100 rad/sec

b) step is applied at t=0.5 sec:

157 rad/sec at 0.5 sec

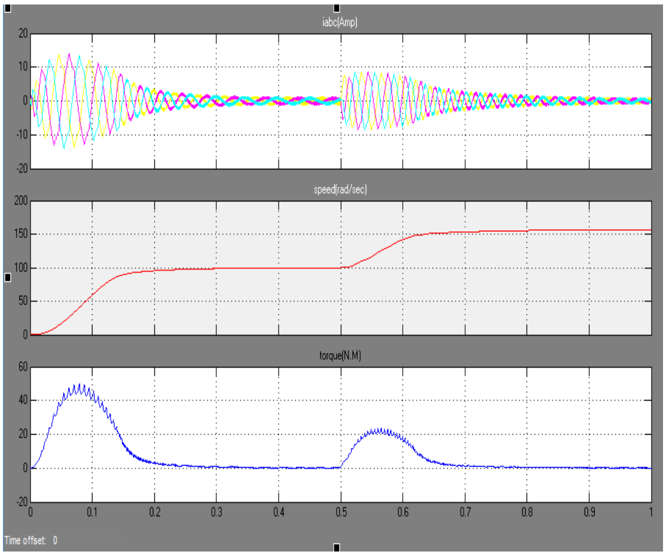


Fig 16: 3 -ϕ currents, Speed, and Torque for step signal

IX. CONCLUSION

In this thesis, Sensorless control of induction motor using Model Reference Adaptive System (MRAS) technique has been proposed. Sensorless control gives the benefits of Vector control without using any shaft encoder. In this thesis the principle of vector control and Sensorless control of induction motor are given elaborately. Simulation results of Vector Control and Sensorless Control of induction motor using MRAS technique were carried out by using Matlab/Simulink. From the simulation results, the following observations are made.

i) The transient response of the drive is fast, i.e. we are attaining steady state very quickly.
ii) By using MRAS we are estimating the speed, which is same as that of actual speed of induction motor.

Thus by using sensor less control we can get the same results as that of vector control without shaft encoder. Hence by using this proposed technique, we can reduce the cost of drive i.e. shaft encoder's cost, we can also increase the ruggedness of the motor as well as fast dynamic response can be achieved.

REFERENCES

1. Abbondanti, A. and Brennen, M.B. (1975). "Variable speed induction motor drives use electronic slip calculator based on motor voltages and currents". IEEE Transactions on Industrial Applications, vol. IA-11, no. 5: pp. 483-488.
2. Nabae, A. (1982). "Inverter fed induction motor drive system with and instantaneous slip estimation circuit". Int. Power Electronics Conf., pp. 322-327.
3. Jotten, R. and Maeder, G. (1983). "Control methods for good dynamic performance induction motor drives based on current and voltages as measured quantities". IEEE Transactions on Industrial Applications, vol. IA-19, no. 3: pp. 356-363.
4. Amstrong, G. J., Atkinson, D. J. and Acarnley, P. P. (1997). "A comparison of estimation techniques for sensorless vector controller induction motor drives". Proc. Of IEEE-PEDS.
5. Wang yaonan,lu jintao,haung shoudao(2007)."speed sensorless vector control of induction motor based on MRAS theory".
6. Dao hung anh; pham dinhtruc(2005) ."Model reference adaptive system based sensorless control of induction motor".
7. "Modern power electronics and ac drives" by BIMAL K.BOSE
8. "Electric motor drives modeling, analysis and control" by R.KRISHNAN.

AUTHOR PROFILE

G.Pydiraju was born in 1988. Studying M.Tech (Power And Industrial Drives) in Vignan's Institute Of Information Technology. And he received B.TECH (EEE) from chaitanya engineering college.

M.Daivaasirvadam was born in 1987.He received his M.Tech (Computer Controlled Industrial Power) degree in electrical and electronics from NIT, Calicut. Received B.TECH from GIET engineering college of JNTU Hyderabad. Presently he is working As Assistant Professor In Vignan's Institute Of Information Technology.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)