

# Rotor Speed Estimation for Vector Controlled Induction Motor Drive using MRAS

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**Abstract:** The term sensorless vector control means vector control without any speed sensor. Sensorless vector control drives have main benefits over vector control drives as reliability and low cost. Speed of the motor can be estimated using Motor terminal voltages and currents. If we know the certain parameters of the induction motor, using these parameters and reference frame theory we can construct the mathematical model of motor. This model is used for speed estimation. In this paper speed of induction motor is estimated using model reference adaptive system and system is simulated using MATLAB. Simulation results of estimated speed is correct.

**Keywords:** sensorless speed estimation, MRAS.

## 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.[1] 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 [1,2]. 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.

In a MRAS system, rotor flux-linkage components,  $\Psi_{dr}^s$ ,  $\Psi_{qr}^s$  of the induction machine (which are obtained by

using measured quantities, e.g. stator voltages and currents) are estimated in a reference model and are then compared with,  $\Psi_{dr}^s$ ,  $\Psi_{qr}^s$  estimated by using an adaptive model [3]. Then effort is made to reduce this error to zero using adaptive mechanism (fig 1).

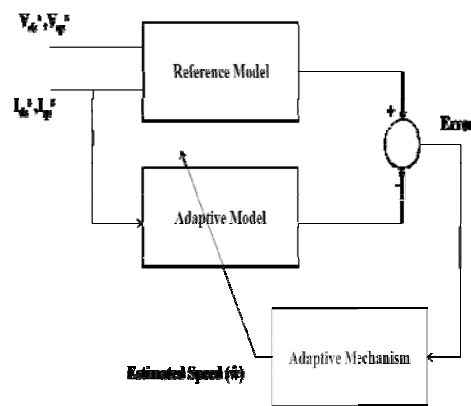


Fig. 1 MRAS for estimation of speed

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. MODELLING OF INDUCTION MOTOR

In order to decouple the torque producing and flux producing components of input voltages and currents to the induction motor, Modelling of induction motor is done in stationary reference frame [4].

### A. Reference model

Stator voltage equation for  $V_{ds}^s$  in  $d^s - q^s$  equivalent circuit can be written as:

$$V_{ds}^s = R_s i_{ds}^s + L_{ls} \frac{d}{dt} (i_{ds}^s) + \frac{d}{dt} (\Psi_{dm}^s) \quad (1)$$

$$V_{qs}^s = R_s i_{qs}^s + L_{ls} \frac{d}{dt} (i_{qs}^s) + \frac{d}{dt} (\Psi_{qm}^s) \quad (2)$$

Where,  $V_{ds}^s, V_{qs}^s$  is  $d^s - q^s$  axis stator voltage respectively,  $i_{ds}^s, i_{qs}^s$  is  $d^s - q^s$  axis stator current respectively,  $R_s, R_r$  is stator, rotor resistance respectively,  $L_{ls}, L_{lr}$  is stator, rotor leakage inductance respectively and  $\Psi_{dm}^s, \Psi_{qm}^s$  is  $d^s - q^s$  axis flux linkage respectively.

We have,

$$\Psi_{dr}^s = \frac{L_r}{L_m} \Psi_{dm}^s - L_{lr} i_{ds}^s \quad (3)$$

$$\Psi_{qr}^s = \frac{L_r}{L_m} \Psi_{qm}^s - L_{lr} i_{qs}^s \quad (4)$$

$$\Psi_{dm}^s = \Psi_{ds}^s - L_{ls} i_{ds}^s \quad (5)$$

$$\Psi_{qm}^s = \Psi_{qs}^s - L_{ls} i_{qs}^s \quad (6)$$

Substituting values of  $\Psi_{dm}^s$  and  $\Psi_{qm}^s$  in equations 3 and 4 we get,

$$\Psi_{dr}^s = \frac{L_r}{L_m} [f(V_{ds}^s - R_s i_{ds}^s) - L_{ls} i_{ds}^s] - L_{lr} i_{ds}^s \quad (7)$$

$$\Psi_{qr}^s = \frac{L_r}{L_m} [f(V_{qs}^s - R_s i_{qs}^s) - L_{ls} i_{qs}^s] - L_{lr} i_{qs}^s \quad (8)$$

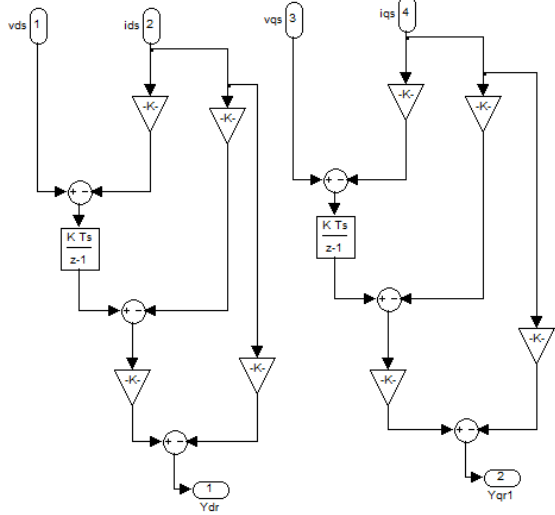


Fig. 2 Reference model.

### B. Adaptive Model

The rotor circuit equations of  $d^s - q^s$  equivalent circuit can be given as:

$$\frac{d}{dt} \Psi_{dr}^s + R_r i_{dr}^s + \omega_r \Psi_{qr}^s = 0 \quad (9)$$

$$\frac{d}{dt} \Psi_{qr}^s + R_r i_{qr}^s + \omega_r \Psi_{dr}^s = 0 \quad (10)$$

Adding term  $(L_m R_r / L_r) i_{ds}^s$  and  $(L_m R_r / L_r) i_{qs}^s$  respectively, on both sides of the above equations. We get,

$$\frac{d}{dt} \Psi_{dr}^s + \frac{R_r}{L_r} (L_m i_{ds}^s + L_r i_{dr}^s) + \omega_r \Psi_{qr}^s = \frac{L_m R_r}{L_r} i_{ds}^s \quad (11)$$

$$\frac{d}{dt} \Psi_{qr}^s + \frac{R_r}{L_r} (L_m i_{qs}^s + L_r i_{qr}^s) - \omega_r \Psi_{dr}^s = \frac{L_m R_r}{L_r} i_{qs}^s \quad (12)$$

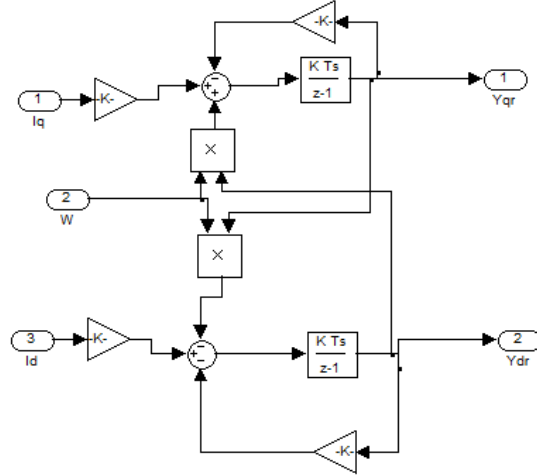


Fig. 3 Adaptive model.

## III. SIMULATION AND RESULTS

Speed estimation block in simulation is constructed using equations 7, 8 and 11, 12 are respectively used as reference model and adaptive model. Model reference adaptive system shown in fig 4 is simulated using MATLAB.

The speed, current and rotor flux responses are observed under various operating conditions such as step change in reference speed, step change in load, etc.

Fig. 5a shows the actual and estimated speed of induction motor when 100 rpm reference is applied for 1sec.

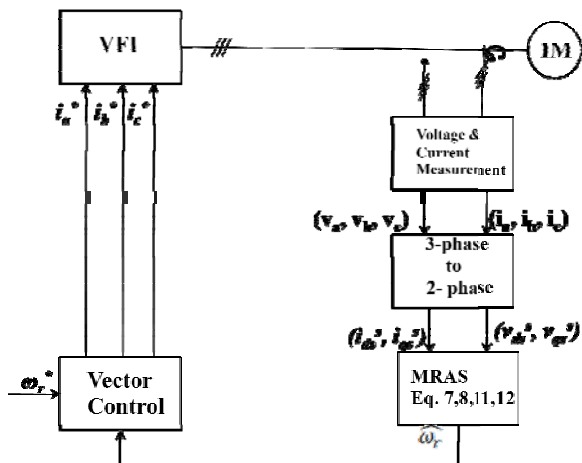


Fig. 4 Block diagram of speed sensorless vector control

Fig. 5b gives error signal for same reference of 100 rpm.



Fig. 5a actual speed and reference speed for 100 rpm.

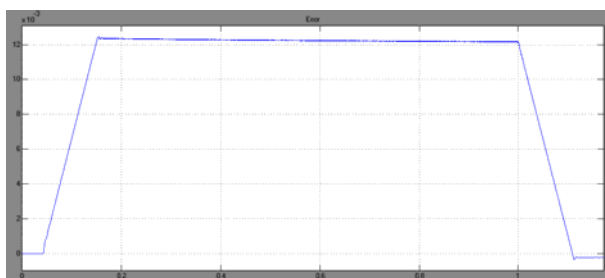


Fig. 5b Error signal for.

Fig. 5c shows the actual and estimated speed responses. Actual speed is 10 rpm pulsed. Fig. 5d shows error signal.

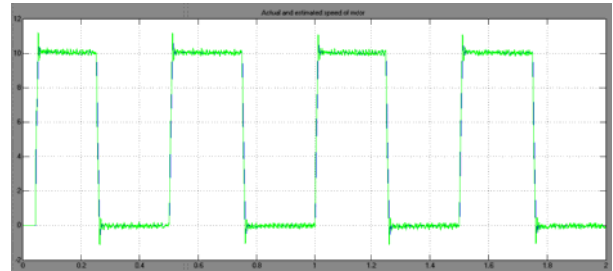


Fig. 5c actual speed and reference speed

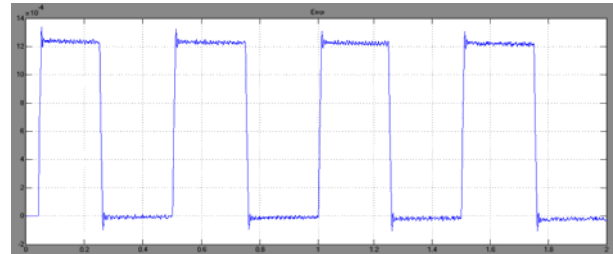


Fig. 5d Error signal.

#### IV. CONCLUSIONS

Controlled ac drives without mechanical sensors for speed have the attraction of lower cost and higher reliability. A variety of sensorless controlled ac drive schemes are available for practical application. In this paper, a MRAS implemented in the stationary reference frame is proposed to identify the rotor speed of an induction motor. This system is simulated using MATLAB. The results proved that the proposed system can give better overall performance regarding to high estimation accuracy, and has a good convergence performance and better steady identification characteristics.

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