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Sensor-less Vector speed Control of Induction motor Drives using MRAS technique

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Abstract- **A model reference adaptive system (MRAS) is simplest speed estimate technique for controlling induction motor from very low to very high speed range. A reference and adaptive model is used to generate two speeds Nr and Nr*, and its error used to control speed as per requirement. This paper presents a new sensor-less vector control scheme consisting on the one hand of a speed estimation algorithm which overcomes the necessity of the speed sensor and on the other hand two different models with the simplest algorithm. In this work, an indirect field-oriented induction motor drive with a MRAS is presented. The design includes rotor speed estimation from measured stator terminal voltages and currents. The estimated speed is used as feed-forward in an indirect vector control system achieving the speed control without the use of shaft mounted transducers with adaptive control. A MATLAB demonstration is done for a high performance of the control scheme under load disturbances and other parameter uncertainties. In order to model and simulate the electrical system, the simulation software Simulink is used.**

Index Terms- Sensorless, Vector control, indirect field oriented control, Induction motor, MRAS.

I. INTRODUCTION

The field of ac drives has experienced an explosive growth in recent years and its demand reaches at the peak as additional services are being added to existing infrastructure. The control and estimation of induction motor drives constitute a vast subject, and the technology has further advanced in recent years. Induction motor drives with cage type machines have been the workhorses in industry for variable speed application such as includes pumps and fans, paper and textile mills, subway and locomotive propulsion, electric and hybrid vehicles etc. The control and estimation of ac drives in general are considerably more complex than those of dc drives. Vector control is efficient and effective way of controlling speed of 3phase Induction motor drive [1-6].

An indirect vector control of induction motor is a feed-forward control here a motor speed is estimated using various techniques from motor terminal voltages and current. A speed sensor is eliminated due to finite number of limitations such as prone to noise, shaft mounting arrangement, expensive etc. The induction motor is most widely used motor, and in varied applications a desire for high dynamic performance in wide speed range is necessity. The sensorless vector control with speed estimation techniques is the best solution for this situation. The simple yet robust control is another basic need. Thus, MRAS system is boon having two controllers with easiest algorithm.

In recent literature, many researchers have carried out the design of sensorless vector of IM drives based on the Model reference Adaptive Scheme, Extended Kalman Filter, Luenberger Observer, also Artificial Neural Network [7-14].

This paper presents the Model reference adaptive system (MRAS) for sensorless speed control using MATLAB simulations, and results for various speed and torque is discussed. MATLAB Simulink software is used for simulation of this model.

II. MODEL REFERENCE ADAPTIVE SYSTEM

The good result and ease of implementation has diverted users most attention to MRAS, out of all the available methods; sensorless vector control of induction drives. There are number of advantages of MRAS sensorless control such as; Wide speed range from very low to very high speed, high dynamic performance of drives in steady state as well as transient states, robust to parameter variations, simpler algorithms and cheap running cost etc. The MRAS makes use of two independent machine models of different structures to estimate the same state variable (Wm) [16]. The structure that does not contain the variable that should be estimated, e.g. rotor speed, is considered as a reference model. However, the structure that contains the variable to be estimated is treated as an adjustable or adaptive model. The error between the outputs two controllers is used to apply suitable adaptive mechanism. The speed correctly estimated for control is defines when the error between these two controls converges to zero. The estimated speed is then equal to the actual motor speed. This adaptation is made possible with the PI controller.

Figure 1 illustrates the schematic block of a MRAS based speed estimator.

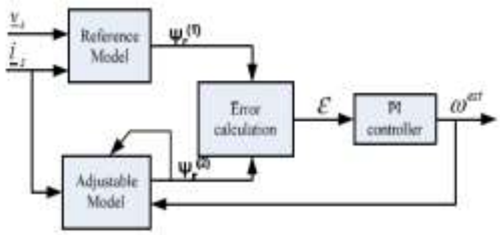

Fig.1 The schematic block of a MRAS based speed estimator.

In this block diagram ψr(r) is output of reference model, whereas ψr(a) is output of adaptive model, these are two estimates of the rotor flux space vector in stationary reference frame. The open loop voltage model is widely used as reference system because of the lack of speed in it and because of its simplicity and relatively robustness against motors variation.

The reference model and adaptive model are denoted by equation (1) and (2)

$$Vs = Rs\ is + \frac{d\psi s}{dt} \qquad (1)$$

$$0 = Rr\ ir + \frac{d\psi r}{dt} - j\omega r\ \psi r \qquad (2)$$

Rotor flux of induction motor drives is computed as:

$$\frac{d\psi r}{dt} = \frac{Lr}{Lm}\left[Vs - Rs\ is - \sigma\ Ls\ \frac{dis}{dt}\right] (3)$$

$$\frac{d\psi r}{dt} = \left[-\frac{1}{Tr} + j\omega r\right]\ \psi r + \frac{Lm}{Tr}\ is \quad (4)$$

From Equations (1) a rotor flux space vector can be obtained, and as the equation is free of Rotor speed term, it is said to be Reference model. Also, a space vector of rotor flux is obtained from equations (2), where rotor speed term is present thus, it is a adaptive model. Equation (3) and (4) represents the rotor flux space vector. By resolving equations (3) and (4) for two axis component i.e. a rotor flux vector in stationary reference frame we get the following equations:

$$p\begin{bmatrix}\psi rx\\ \psi ry\end{bmatrix} = \frac{Lr}{Lm}\left[\begin{bmatrix}Vsx\\ Vsy\end{bmatrix} - \begin{bmatrix}(Rs + \sigma Lsp) & 0\\ 0 & (Rs + \sigma Lsp)\end{bmatrix}\begin{bmatrix}isx\\ isy\end{bmatrix}\right]$$
(5)

$$p\begin{bmatrix}\psi rx\\ \psi ry\end{bmatrix} = \begin{bmatrix}\frac{-1}{Tr} & -\omega r\\ \omega r & \frac{-1}{Tr}\end{bmatrix}\begin{bmatrix}\psi rx\\ \psi ry\end{bmatrix} + \frac{Lm}{Tr}\begin{bmatrix}isx\\ isy\end{bmatrix} (6)$$

Where,

$$\sigma = 1 - \left(\frac{Lm^2}{LsLr}\right)$$

$$p = \frac{d}{dt}$$

Also, Vs, Is, Ir, ψs, ψr are the stator voltage, stator and rotor current, stator and rotor flux vectors. Rs and Rr are stator and rotor resistance and ωm is a rotor speed.

$$\omega^2 st = Kp\ \epsilon + Ki \int \epsilon\ dt$$

$$\epsilon = \psi ry^{(r)}\psi rx^{(a)} - \psi rx^{(r)}\psi ry^{(a)}$$

These two rotor fluxes equations (5) and (6) are used for tuning the speed signal (error signal). The error signal is tuned in MRAS using simple PI controller. The adaption algorithm converge the error between two rotor fluxes to zero and so the speed control is obtained.

III. MATLAB Simulation Work

A MATLAB is a high performance language designed for technical computing. A simulation for MRAS system is carried out using MATLAB. A DC supply of 400V is used as a source to the system. This 400V DC supply is stepped up using a DC to DC converter commonly known as Boost converter, The Boost converter steps the voltage up at 750-800V approx. This voltage is then fed to 3 phase full bridge inverter for converting it to DC to AC supply with finite frequency. The 3 phase inverter has 6 thyristor switches with diode for DC to AC conversion, these Thyristor switches are controlled with Gate pulse generator. Fig.2 shows the MATLAB simulation diagram for MRAS sensorless control of Induction motor drive.

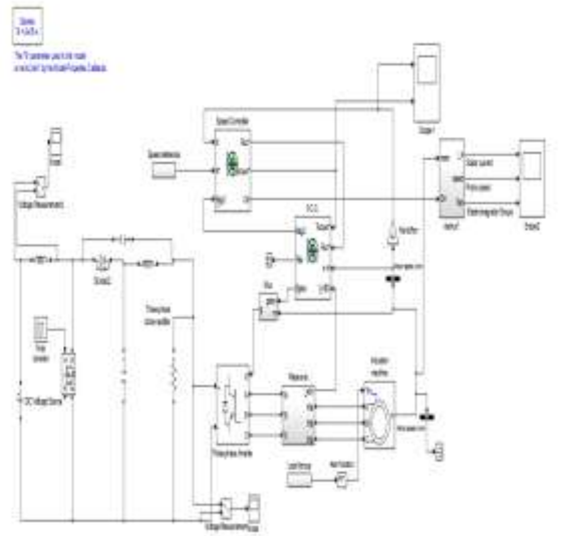

Fig.2 Simulation of MRAS Sensorless vector control for Induction motor drives in MATLAB.

The 3 phase Induction motor, squirrel cage type's speed is to be controlled under steady state and transient state. The terminal voltages and current are taken for converting to 3 phase to 2 phase component (Id and Iq). These Id and Iq are current responsible for Flux and Torque. This conversion is Clark's transformation and vice a versa is Parks transformation. The conversions are carried out using FOC (Field oriented control) block.

The speed control block is the block which will give reference torque and reference flux from reference speed pre decide. These reference torque and flux (Te* and ψ*) then generate the reference Iabc to feed to Induction motor through gate signal. As the speed tuning error at FOC block is made zero using simple PI controller, the speed control is obtained.

IV.MATLAB RESULT

The control speed of induction motor drive for 500 rpm reference speed and 1000 reference torque, the control speed is obtained at 0.55 sec the motor toque is fluctuating at 650-1200 and rotor speed is maintained at 1000 rpm constant, despite of varying torque. The simulation results for the 1000 rpm speed at 1000 torque are shown in Fig.3 as below:

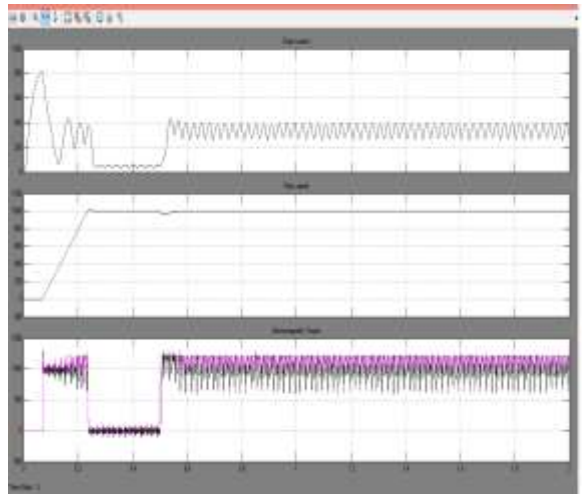

Fig.3 Simulation Results for 1000 torque and 1000rpm speed.

And for 500 rpm reference speed and 500 reference torque, the control speed is obtained at 0.55 sec the motor toque is maintained constant 550 and rotor speed is maintained at 1000 rpm constant. The simulation results for 1000 rpm speed at 500 torque are shown in Fig.4 as below:

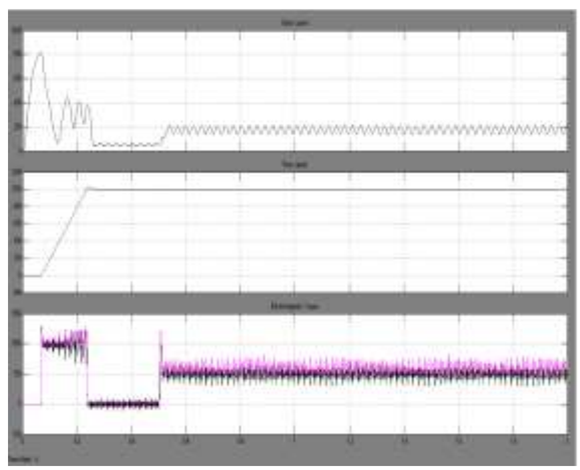

Fig.4 Simulation Results for 500 torque and 1000rpm speed.

The simulation result shows the constant speed output for are variation in input torque, which shows the system is robust in steady state as well as transient conditions.

V.CONCLUSION

The MRAS sensorless control for induction motor is boon to industrial applications of induction motor drive from small to multi horsepower. The MATLAB simulation shows the constant controlled speed output for varied input torque. Hence, the MRAS system is robust in all steady state and transient conditions.

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