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FPGA–Based implementation of Stator Current Observer for sensorless induction motor drive

C. Kamal Basha[1], Ganesh V.[2], Chinna Kullay Reddy D.[3] and Rajangam K.[4]

ABSTRACT

The aim of this paper is to present speed estimation method for sensorless indirect field oriented controlled Induction Motor (IM) drive. The proposed Model Reference Adaptive System (MRAS) based on stator currents is used for the estimation of the rotor speed. The problems related to integrationof the variables in the reference model of MRAS, here stator currents measured in the IM model are used as reference model. Assessed stator currents by means of current model, depends on speed to be estimate used as adjustable model. The differences in signal between assessed and measured currents are adjusted by new adaption algorithm such that output of the model is estimated speed. The proposed new stator current based MRAS is tested numerically on FPGA real time simulation platform with prototype. Performance of the drive with new MRAS was tested by developing a prototype model.

Keywords: MRAS, Sensorlesscontrol , FPGA, Induction motor

1. INTRODUCTION

Usually speed sensor is used to measure speed of the IM.Performances of the sensors are affectedbymechanical shocks,varying environmental conditions, etc. at the same time reliability of the IM reduces and increases cost. Several control techniquesalready been proposed in the literature for the estimation of the rotor speed. Speed estimation using flux estimation through current and voltage models of the IM have been discussed in [1, 2]. Estimation of all state variables of IM using full order observers[3] – [8] is sensitive to noise.

For the estimation rotor speed, MRAS is one kind of observer. The Principle of MRAS is based on, outputs of two models – one autonomous model not dependent on the quantity to be estimate i.e. rotor speed and the secondmodeldependent on the quantity to be estimatecalled as adjustable model.

MRAS based on the rotor flux proposed by Tami [10, 18] is more popular. In this MRAS, rotor flux is obtained by current and voltage models. The error between these two models through PI controller is used to estimate the rotor speed.Second type is back EMF based MRAS scheme[11], in which rotor speed of the IM is estimatedthrough error between measured and estimated back EMF. Another class of MRAS is based on the stator currents [12], the stator currentsarecalculated by appropriate stator current model and are equated with measured currents. Difference between these two through suitable adaption algorithm is used to obtain the rotor speed

In this paper, MRAS adaption algorithm is proposed, in that measured stator currents of the IM areconsidered as a reference model, and these currents areequated with the adjustable model stator currents. Stator current-voltage model are used to estimate the currents in adjustable model and same are adjusted with the rotor speed calculated by the adaptation algorithm by making use of estimated rotor flux vector.

[1],[4] Associate Professor Department of Electrical Engineering. Madanapalle Inst. of Technology and science, Madnapalle, A.P. India.

[2] Professor, JNTUCEP, Pulivendula, AP. India.

[3] Asst. Professor Dept. of EEE, Madanapalle Inst. of Technology and science, Madnapalle.

2. INDUCTION MOTOR MODEL

The dynamical modeling equationsof IMstationary reference frame is

$$\frac{di_s^s}{dt} = \frac{1}{\sigma L_s}\left(u_s^s - R_s i_s - \frac{L_m}{L_r}\frac{d\lambda_r^s}{dt} \right) \tag{1}$$

$$\frac{d\lambda_r^s}{dt} = \frac{L_m}{T_r} i_s^s - \left(\frac{1}{T_r} - J\omega_r \right) \lambda_r^s \tag{2}$$

IM model in terms of stator current and fluxis

$$\frac{d}{dt}\begin{bmatrix} i_s^s \\ \lambda_s^s \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}\begin{bmatrix} i_s^s \\ \lambda_s^s \end{bmatrix} + \begin{bmatrix} b_1 \\ 0 \end{bmatrix} u_s^s \tag{3}$$

The electromagnetic torque produced in induction motor is

$$T_e = p * \lambda_T^s \oplus i_s^s \tag{4}$$

The mechanical relation between load torque and speed is given by

$$\frac{d\omega}{dt} = \frac{N_p}{J}\left(T_e - T_L \right) \tag{5}$$

3. MODEL REFERENCE ADAPTIVE SYSTEM

It has two models i.e reference model and adjustable, the between these two models with suitable adaption algorithm is used for estimation of rotor speed.

3.1. Mathematical model ofrotor flux basedMRAS

Reference model [8] is

$$\frac{d}{dt}\begin{bmatrix} \lambda_{dr}^s \\ \lambda_{qr}^s \end{bmatrix} = \frac{L_r}{L_m}\left(\begin{bmatrix} u_{ds}^s \\ u_{qs}^s \end{bmatrix} - \begin{bmatrix} \left(R_s + \sigma L_s S \right) & 0 \\ 0 & \left(R_s + \sigma L_s S \right) \end{bmatrix}\begin{bmatrix} \lambda_{dr}^s \\ \lambda_{qr}^s \end{bmatrix} \right) \tag{6}$$

And the adjustable model is

$$\frac{d}{dt}\begin{bmatrix} \hat{\lambda}_{dr}^s \\ \hat{\lambda}_{qr}^s \end{bmatrix} = \begin{bmatrix} \left(-\frac{1}{\tau_r} \right) & \left(-\omega_r \right) \\ \omega_r & \left(-\frac{1}{\tau_r} \right) \end{bmatrix}\begin{bmatrix} \lambda_{dr}^s \\ \lambda_{qr}^s \end{bmatrix} + \frac{L_m}{T_r}\begin{bmatrix} i_{ds}^s \\ \lambda_{qs}^s \end{bmatrix} \tag{7}$$

The flux estimator equation 6 and 7 independently calculates the rotor flux. Rotor speed is estimated using error between these twomodels through PI controller.

$$\omega_r = K_p \in + K_I \int \in dt,$$

$$\hat{\omega} = \left(K_p + K_I \right)\left[\lambda_{qr}^s \hat{\lambda}_{dr}^s - \lambda_{dr}^s \hat{\lambda}_{qr}^s \right] \tag{8}$$

From the equation (8) the estimated speed using MRAS is obtained.

3.2. Proposed Stator current MRAS estimator

The stator current is measured by using MRAS adaption algorithm. The rotor speed is calculated by error between two values. The mathematical modeling equations is as follows.

$$\frac{d\hat{\lambda}_{dr}^{s}}{dt} = -\frac{1}{T_r}\hat{\lambda}_{dr}^{s} - \widehat{w}_r\hat{\lambda}_{qr}^{s} + \frac{L_m}{T_r}i_{ds}^{s} \tag{9}$$

$$\frac{d\hat{\lambda}_{qr}^{s}}{dt} = -\frac{1}{T_r}\hat{\lambda}_{qr}^{s} - \widehat{w}_r\hat{\lambda}_{dr}^{s} + \frac{L_m}{T_r}i_{qs}^{s} \tag{10}$$

$$\frac{d\hat{i}_{ds}^{s}}{dt} = \frac{1}{T_r}\hat{\lambda}_{dr}^{s} - \beta\widehat{w}_r\hat{\lambda}_{qr}^{s} - K_1 i_{ds}^{s} + K_2 u_{ds} \tag{11}$$

$$\frac{d\hat{i}_{ds}^{s}}{dt} = \frac{1}{T_r}\hat{\lambda}_{dr}^{s} + \beta\widehat{w}_r\hat{\lambda}_{qr}^{s} - K_1 i_{ds}^{s} + K_2 u_{ds} \tag{12}$$

Where $\hat{i}_{ds}^{s}$ and $\hat{i}_{qs}^{s}$ are the estimated stator current components, $\hat{\lambda}_{dr}^{s}$ and $\hat{\lambda}_{qr}^{s}$ are estimated rotor flux components.

The rotor speed $\widehat{\omega}_r$ through adaption algorithm is

$$\widehat{\omega}_r = K_P\left(\overline{i}_{qs}^{s}\hat{\lambda}_{dr}^{s} - \overline{i}_{ds}^{s}\hat{\lambda}_{qr}^{s}\right) + K_I\int\left(\overline{i}_{qs}^{s}\hat{\lambda}_{dr}^{s} - \overline{i}_{ds}^{s}\hat{\lambda}_{qr}^{s}\right)dt$$

From the above analysis, use of estimated speed in adjustable modelis shown in figure 1.

Where L_m Mutual inductance, L_s, L_r are stator and rotor leakage inductances, T_r rotor time constant, ω_r rotor angular speed,

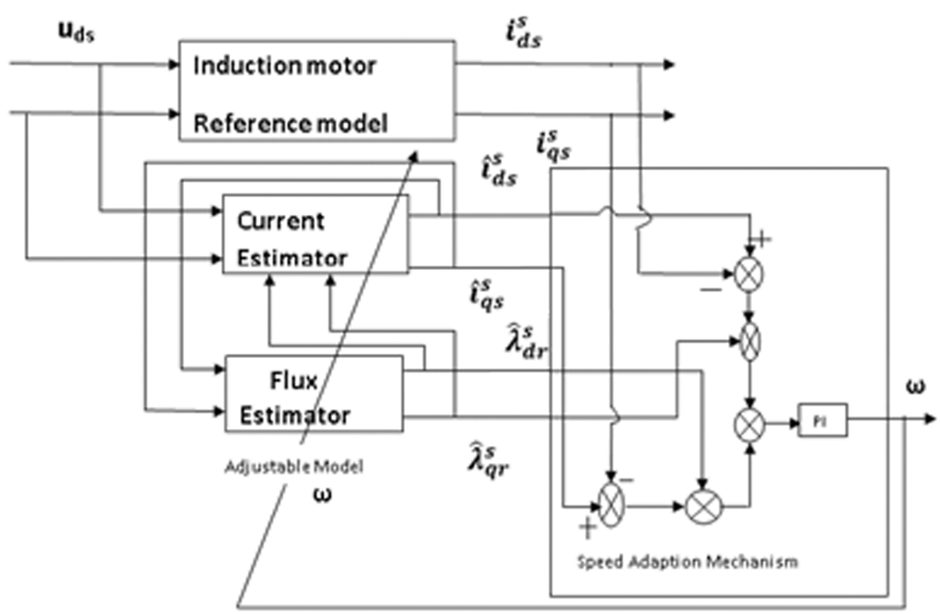
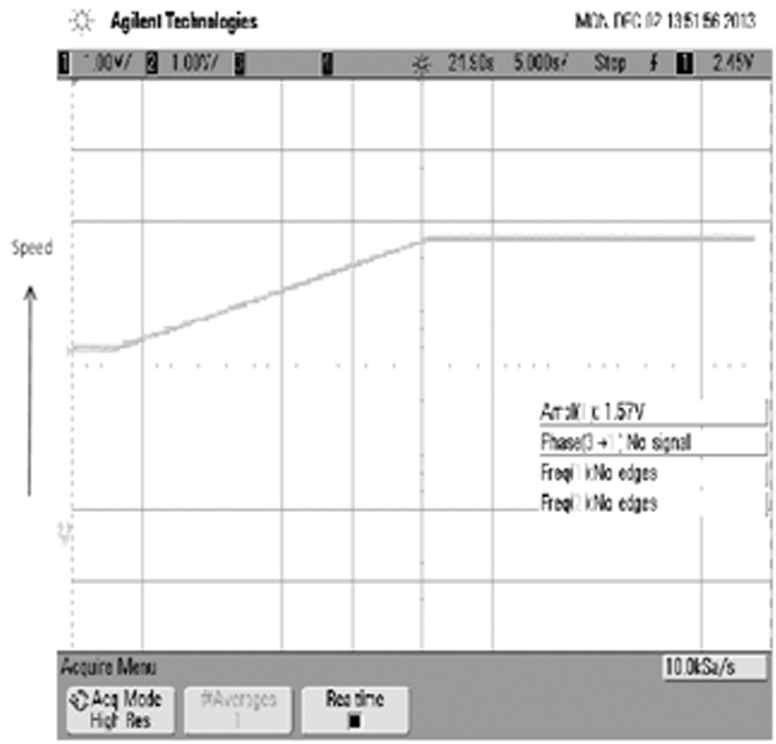


Figure 1: Stator current based MRAS scheme

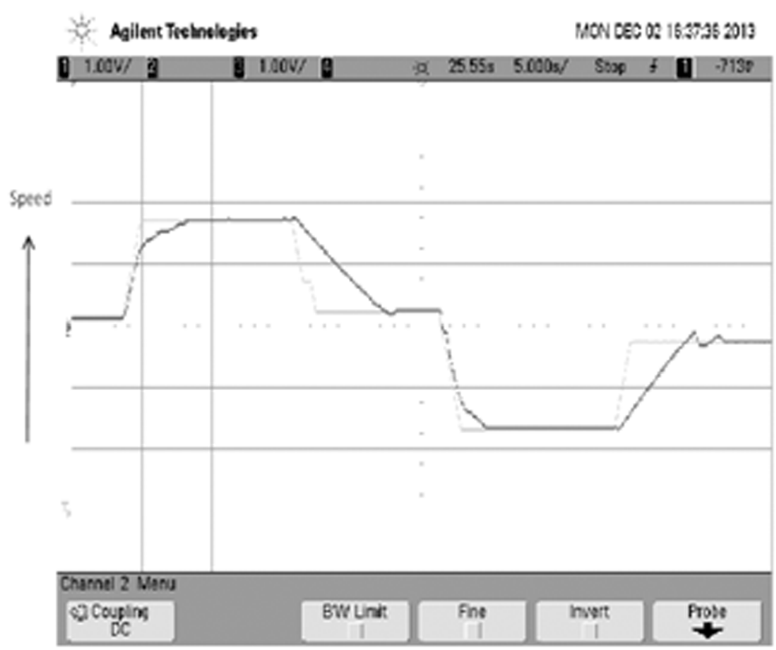
4. RESULTS

The transientresponse of the IMwithnew proposed MRAS estimator for IFOC induction motor was tested numerically on FPGA real time simulation platform with prototype.

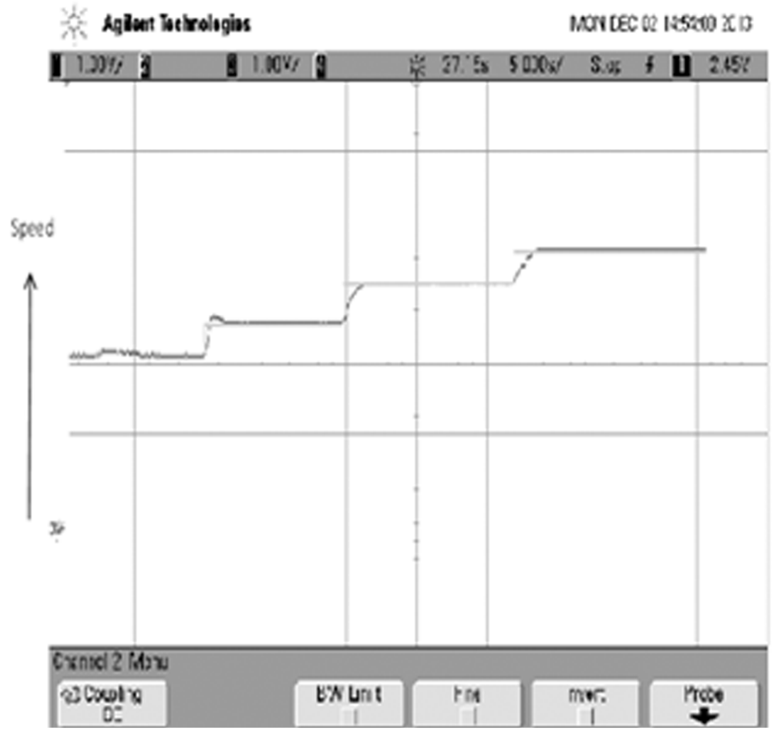
Figure 2 shows the dynamic behavior of command and actual rotor speedusing proposedMRAS scheme. The speed is increased 1400 rpm linearly in 0.5sec, it shows that real rotor speed follows the command signal with improved transient response, at 1400rpm it is observed that there is 2% of steady state error. The response of the IM in forward and regenerative operation shown in Figure (b) . Hear the speed increased



(a)



(b)



(c)

(d)

Figure 2: Response of the proposed based MRAS (a) desired and actual speed from 0 to 1400rpm (b) forward and regenerative speed operation (c) step change in torque (d) Stator currents

form 0 to 1400 rpm and it is maintained constant upto t=4sec and decreased to -1400 rpm. Figure (c) shows the step change in torque from no load to rated torque in the steps of 1.25N-M. Figure (d) shows the stator currents.

5. CONCLUSIONS

A sensorlessIFOC drive with new MRAS adaption algorithm was analyzed. By using the stator current based MRAS scheme thedynamic response of the IMhas been improved in terms of the settling time, peak overshoot andrise time.

REFERENCES

[1] Rajasekara.K, Kawamura.A, K.Matsuse, "Sensorless Control of AC Motor Drives: Speed and Position Sensorless Operation", IEEE Press, Piscataway, NJ, 1996.

[2] L. Ben Brahim, S. Tadakuma, and A. Akdag, "Speed control of induction motor without rotational transducers," IEEE Trans. Ind. Appl., vol. 35, no. 4, pp. 844–850, Jul./Aug. 1999.

[3] Hisao Kubota, KoukiMastuse and Takayoshi Nakano, "DSP based speed adaptive flux observer of induction motor", IEEE Trans. on Industry Applications, Vol. 29, No.2, 1993, pp. 344-348.

[4] Abbou, A.; Mahmoudi, H. "Implementation of a Sensorless Speed Control of Induction Motor Using RFOC Strategy" International Review of Electrical Engineering(IREE), pp. 730-737, JUL-AUG 2008.

[5] E. Levi and M.ang, "A speed estimator for high performance sensorless control of induction motor in the field weakening region" IEEE Trans.Power Electronics, vol. 17, no. 3, pp. 365-378, May 2002.

[6] Y.R.Kim,K.S.Sul and M.H.Park, "Speedsensorless vector control of induction motor using extended Kalman filter" IEEE Trans. Ind. Appl., vol.30, no.5, pp. 1225-1233, Sep/Oct. 1994.

[7] Zhang Wei, Cai Wei Sheng "Flux Observer for Field Oriented Induction Motors based on EKF" 2010 2nd International Conference on Software Technology and Engineering (ICSTE) pp. v2-240-v2-243.

[8] M.BenHamed and L.Sbita, "Speed Sensorless Indirect Stator Field Oriented Control of Induction Motor based on Luenberger observer", IEEE-ISIE06-2006.

[9] Mezouar, A.; Fellah, M. K.; Hadjeri, S. "Speed sensorless vector control of induction motors using singularly perturbed sliding mode observer" International Review of Electrical Engineering(IREE), pp. 398-405, MAY-JUN 2007.

[10] K. Gherram, K.Yazid and M. Menaa "Sensorless Indirect Vector Control of an Induction Motor by ANNs Observer and EKF" 18th Mediterranean Conference on Control & Automation Congress Palace Hotel, Marrakech, Morocco June 23-25, 2010, pp. 521-526.

[11] M. M. Krishan, "Sliding Mode Control with MRAC Technique Applied to an Induction Motor Drives" International Review of Automatic Control (IREACO) Vol. 1. n. 1, pp. 42-48, May 2008.

[12] Hu Jun B.R.uggal and M.V.ilathgamuwa, "A MRAS based speed sensorless field oriented control of induction motor with on line stator resistance tuning" IEEE Trans. Ind. Appl. 1998.

[13] S. Tami, H. Sugimoto and Y. Masao "Speed sensorless vector control of induction motor with model reference adaptive system" in conf.IEEE/IAS. Annu.Meeting, 1987,pp. 189-195.

[14] M. Rashed and A.F. Stronach, "A stable back-EMF MRAS based sensorless low speed inaction motor drive insensitive to stator resistance variation," Proc.Inst.Elect.Eng Elect. Power Appl., vol. 151, no. 6, pp 1685-693, nov. 2004.

[15] T. Orlowska-Kowaska and M. ybkowski, "Novel MRAS type rotor speed and flux estimator for speed sensorless induction motor drive,"Elct.Rev.(polond), vol. 82, no. 11, pp. 35-38, 2006.

[16] M. Mostefai, A. Bendiabdellah "A MRAS-based Speed Sensorless Vector Control of Induction Motor with Rotor-Inverse Time Constant Adaptation" International Review of Automatic Control (IREACO), Vol. 1, pp. 49-56, May 2008.

[17] C. Kamal Basha and M. Suryakalavathi "Speed sensorless vector control of Induction motor using Stator current based MRAS Scheme" International Review of Automatic Control (I.RE.A.CO.), Nov. 2011

[18] A. Sudhakar and M.Vijaya Kumar ""'A Comparative Analysis of PI and Neuro Fuzzy Controllers in Direct Torque Control of Induction motor drives"" International Journal of Engineering Research and Application, Vol 2, Issue 4, June-July 2012, pp 672-680