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Original Research Article

# ONLINE IDENTIFICATION OF STATOR RESISTANCE FOR ROTOR FLUX MRAS BASED SPEED SENSORLESS FIELD ORIENTED CONTROLLED INDUCTION MOTOR DRIVE

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**Abstract:** The paper proposes the stator resistance and machine speed estimation strategy based on rotor flux based MRAS in a systematic manner. This paper presents online method of estimating the stator resistance of an induction motor inconjuction with the motor rotor speed to improve the performance of rotor field oriented control technique. Since stator resistance varies with temperature operating conditions, stable operation in low speed requires an appropriate on-line observer for the stator resistance. It enables the correct speed estimation and stable drive operation at low speed. The proposed parallel speed with stator resistance estimator is verified by MATLAB/SIMULINK simulation software. A simulation result shows the effectiveness, robustness and accuracy of the proposed method.

**Keywords:** Induction motor, model reference adaptive control, stator resistance estimator, sensorless vector controls.

***Introduction:*** Field oriented controlled (FOC) induction motor (IM) drives have become popular in the industry due to its high dynamic response [1]. Knowledge of speed is mandatory for the operation of speed sensorless FOC induction motor (IM) drives. In speed sensor based FOC-IM drives, rotor speed is measured using a sensor usually encoder or tachogenerator or may be estimated using machine terminal voltage and current signals. The use of speed sensor has become obsolete as it suffer from the problems, such as, reduction in robustness and reliability of the drive, need of special mounting arrangement of shaft extension and increases in overall cost of the drive. Therefore, a speed sensor-less drive is preferred over the traditional speed sensor field oriented-controlled IM drive. The available speed estimation techniques may be broadly classified into model-based and signal injection-based approaches.

Indirect vector or field oriented controlled induction motor drives are increasingly used in high-performance drive systems. Exact

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knowledge of stator resistance is not required in indirect field oriented control scheme. Speed sensorless control of induction motor drives attracted great attention of researchers to avoid the different problems associated with direct speed sensors. A most of motor speed estimation schemes rely on induction motor model in the process of speed estimation [1] and require an exact knowledge of all the motor parameters such as stator resistance, so the more attention in stator resistance adaptation appeared recently, with the advances of speed sensorless systems. An accurate value of the stator resistance has importance to improve the operation of a sensorless drive, any error between the actual value and the value used within the model of speed estimation may cause to a substantial speed estimation error. Therefore, the research community has received a special attention to develop online stator resistance identification schemes for accurate speed estimation in the low speed region. The most popular methods include different types of estimators which often use an adaptive algorithm to update the value of stator resistance [5], [7], [9], [13]. In general, most of the methods depends on stator current measurement and require information regarding machine terminals such as machines stator voltages as well (measured or reconstructed).

A method for stator resistance estimation along with speed estimation using flux on rotor side based model reference following adaptive system (MRAS) is proposed. MRAS is used here because of high speed of adaptation, it is easy to implement and involve less computation. MRAS calculates the one quantity in two different ways; one is function of the signal and other dependent on it. Stator resistance estimation mechanism is evolved for correct implementation of field orientation using the rotor flux based MRAS speed estimator and it operates in the stationary reference frame. It does however use the idea related to the creation of the error vector for adaptive stator resistance identification. The tuning signal is formed on the basis of differences in rotor flux component, obtained at the output of the reference and the adjustable model. Here, the role of the reference and the adjustable model is complementary for the purposes of speed and stator resistance. However, the operation of the speed and stator resistance estimators is in simultaneously occurs rather than sequential. The MRAS speed estimator generates the difference formed by instantaneous phase difference between the two estimates of the flux on rotor side while error quantity for stator resistance estimation using the difference in magnitude of two rotor flux estimates. A detailed derivation of the parallel rotor speed and stator resistance estimation process is provided in the paper and the proposed method is used in IFOC of IM drive verified by MATLAB/ Simulation.

**Speed Estimation Method:** The speed is calculated by the Model following Reference Adaptive System (MRAS), where the output of a reference model is compared with the output of an adjustable model or adaptive model until error between two models is vanish to zero. A block diagram for speed estimation by the MRAS technique is shown in Fig. 1 it relies on the machine stator voltages measured and measured current signals and is composed of the reference (voltage) and the adjustable (current) model. The motor speed estimator operates in the stationary reference frame and it is described with the following equations:

$$\frac{d\Psi_{rV}^{s}}{dt} = \frac{L_r}{L_m}[\bar{v}_s^s - (\hat{R}_s + \sigma L_s S)\bar{i}_s^s] \qquad (1)$$

$$\frac{d\Psi_{rI}^{s}}{dt} = \frac{L_m}{T_r}\bar{i}_s^s - (\frac{1}{T_r} - j\hat{\omega}_r)\hat{\Psi}_{rI}^{s} \qquad (2)$$

$$\hat{\omega}_r = \xi\,(K_{P\omega} + \frac{K_{I\omega}}{s}) \qquad (3)$$

$$\xi = X - Y$$

$$= \hat{\Psi}_{drI}^{s}\,\hat{\Psi}_{qrV}^{s} - \hat{\Psi}_{drV}^{s}\,\hat{\Psi}_{qrI}^{s} \qquad (4)$$

Where error vector,

Where, $K_{P\omega}$ *and* $K_{I\omega}$ is the gain of PI controller.

The current model flux equations (2) are defined as adaptive model. This model calculates the fluxes from the stator current only if the speed is known

With the correct speed signal fluxes calculated from the reference model and adjustable model matches i.e. $\hat{\Psi}_{drV}^{s} = \hat{\Psi}_{drI}^{s}$ and $\hat{\Psi}_{qrV}^{s} = \hat{\Psi}_{qrI}^{s}$, where $\hat{\Psi}_{drI}^{s}$ and $\hat{\Psi}_{qrI}^{s}$ are the adaptive model output. An adaptation algorithm with P-I control, as indicated

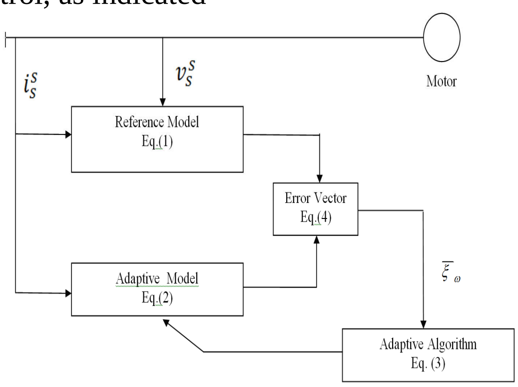



Fig. 1 Structure for speed estimation by model following reference adaptive control (MRAC) principle

can be used to tune the speed $\hat{\omega}_r$ so that error $\xi = 0$. In designing the adaptation algorithm for MRAS, overall stability of the system is considered and speed converges to the desired value with satisfactory dynamics characteristics. Parameters used for the outputs of the voltage (reference) and current (adjustable) models, respectively whereas subscripts s and r used for stator and rotor circuits, respectively in stationary reference frame. From (1)-(4) and Fig.1, the adaptive mechanism is based on tuning signal obtained from the error between the instantaneous position of rotor flux estimator but the difference in the magnitude of two rotor flux is not utilized. The simultaneous estimation of rotor speed and stator resistance based on MRAS scheme is discussed will make use of this difference in the magnitude of two rotor flux to achieve simultaneous estimation of the two quantities. The reference and the adjustable model will switch their role for this purpose, since the rotor flux estimate of (2) is independent of stator resistance.

**Parallel Stator Resistance and Motor Speed Estimation:** The speed is calculated by the Model Following Reference Adaptive control System (MRAS), where the output of one model called as reference model is compared with the output of other model called as an adjustable model or adaptive model. The output of two models then compared until error is vanish to zero. The estimator is described with the following equations:

$$\frac{d\Psi_{rU}^{s}}{dt} = \frac{L_r}{L_m}[\bar{u}_s^{s} - (\hat{R}_s + \sigma L_s S)\bar{i}_s^{s}] \qquad (1)$$

$$\frac{d\Psi_{rI}^{s}}{dt} = \frac{L_m}{T_r}\bar{i}_s^{s} - (\frac{1}{T_r} - j\hat{\omega}_r)\hat{\Psi}_{rI}^{s} \qquad (2)$$

$$\hat{\omega}_r = \xi\,(K_{P\omega} + \frac{K_{I\omega}}{s}) \qquad (3)$$

Where error vector,

$$\xi = X - Y$$

$$= \hat{\Psi}_{drI}^{s}\hat{\Psi}_{qrU}^{s} - \hat{\Psi}_{drU}^{s}\hat{\Psi}_{qrI}^{s} \qquad (4)$$

Where, $K_{P\omega}$ *and* $K_{I\omega}$ are the gain of PI controller.

The motor speed and stator resistance estimator is designed based on the theory of Popov's Hyperstability [2] to make the system globally stable. For designing an adaptive mechanism initially rotor speed is assumed as a constant, as it varies slowly and the stator resistance of the motor varies with temperature, but variations are slow so that it can be also consider constant.

The structure of the machines rotor speed and stator resistance [16] is shown in Fig. 2. $R_s$ and $\omega$ denote the true values of the stator resistance in the motor and rotor speed, respectively. Also, any mismatch between the estimated and true rotor flux space vectors appears as well.

The error equations for the motor voltage model and current model can be written as:

$$\frac{d\xi_U}{dt} = -\frac{L_r}{L_m}[(R_s - \hat{R}_s)\bar{i}_s^{\,s}] \qquad (6)$$

$$\bar{\xi}_U = \bar{\Psi}^{s}_{rU} - \hat{\Psi}^{s}_{rU} \qquad (7)$$

$$\frac{d\xi_I}{dt} = \left[j\omega - \frac{1}{T_r}\right]\bar{\xi}_I + j(\omega - \hat{\omega})\hat{\Psi}^{s}_{rI} \qquad (8)$$

$$\xi_I = \bar{\Psi}^{s}_{rI} - \hat{\Psi}^{s}_{rI} \qquad (9)$$

The system is hyperstable if the input and output of the block $W$ satisfy the Popov's criterion. The adaptation mechanism for rotor speed estimator is given by

$$\hat{\omega}_r = \left(\overline{\xi_I^T} \times J \times \hat{\Psi}^{s}_{rI}\right)\left(K_{P\omega} + \frac{K_{I\omega}}{s}\right) \qquad (10)$$

and the adaptation mechanism for stator resistance estimator is given by

$$\hat{R}_s = \left(-\overline{\xi_U^T} \cdot i_s\right)\left(K_P + \frac{K_I}{s}\right) \qquad (11)$$

Where $K_{P\omega}$, $K_{P\omega}$, $K_P$ and $K_I$ are the PI controller gain of the rotor speed and stator resistance adaptation mechanisms respectively.

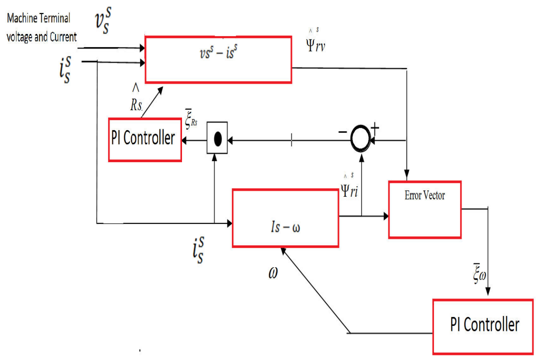



Fig.2 Model Reference Adaptive System (MRAS) structure for parallel estimation of rotor speed and stator resistance

**Results of Speed and Stator Resistance Estimator and discussion**

The block diagram of a sensorless field oriented control of induction motor drive with rotor speed estimator is shown in Fig.3. Simulation using MATLAB Software package, have been carried out to verify the effectiveness of the proposed scheme. The parameters of the induction motor used are given in Table I.

The field oriented control process consist of speed and torque control loop is used, motor voltage and current measured which is used as input to MRAS based speed and resistance estimator, rotating transformation block and sinusoidal pulse width modulation block which produces the correct switching signal pulse for the inverter to achieve the desired performance of the motor.

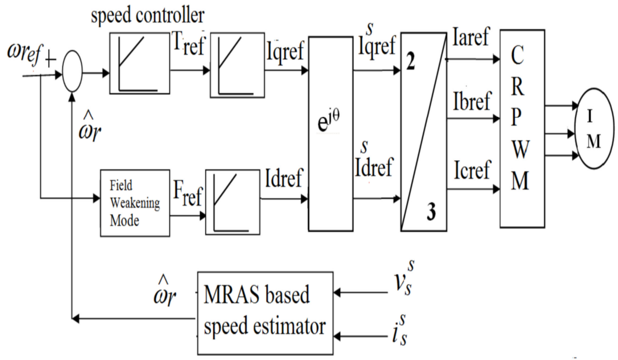
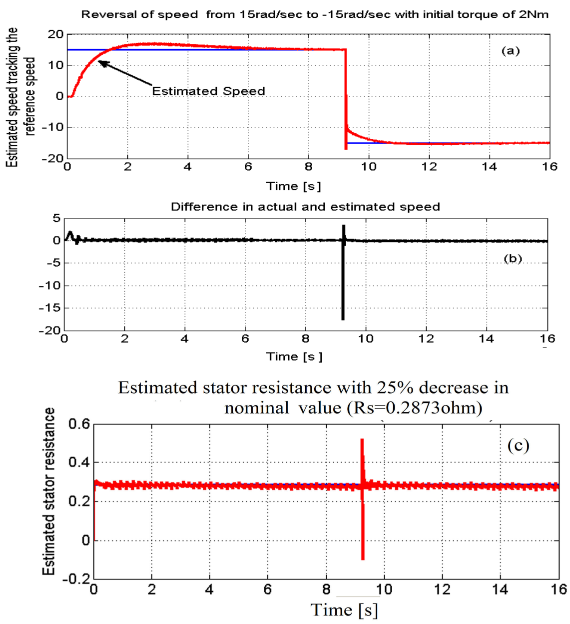



Fig. 3 Indirect field oriented control structure of IM for parallel estimation of rotor speed and stator resistance




Fi Fig.4. Step change in reference speed from 15rad/sec to -15rad/sec at 9 seconds and initial load torque of 2 Nm with 25%

decrease in nominal value of stator resistance (Rs=0.2873ohm).(a) Estimated speed tracking the speed reference (b) Difference between actual and estimated speed.(c) Estimated stator resistance.

Table I: Induction Motor Parameter

| | |
|---|---|
| Rated power | 2.7 KW |
| Rated voltage | 150 V |
| Base frequency | 60 Hz |
| No. of Poles | 4 |
| Stator resistance | 0.3831Ω |
| Stator Inductance | 33.34 mH |
| Rotor resistance | 0.2367 Ω |
| Rotor Inductance | 33.34 mH |
| Mutual inductance | 42.08 mH |

A method of estimating motor speed and the stator resistance in speed sensorless field oriented control of induction motor using the flux based MRAS has been proposed. The proposed MRAS system is simple in nature than its counterpart with speed estimation only and enables very good speed estimation accuracy for step change in the speed command. The proposed stator resistance estimation mechanism output is taken as input for speed estimation improves the speed accuracy and reduces sensitivity with the error in machine stator resistance. The effectiveness of the proposed method verified under various operating condition and in tracking application was verified especially for reversal of speed and gives the good performance.

**References:**


[1] A. B. Proca and A. Keyhani, "Sliding-mode flux observer with online rotor parameter estimation for induction motors", IEEE Transaction on Power Electronics, vol. 54, no. 2, pp. 716-723, Feb 2007.

[2] J. Holtz, "Sensorless control of induction motor drives," Proc. IEEE, vol. 90, no. 8, pp. 1359–1394, Aug. 2002

[3] Y. P. Landau, Adaptive Control: The Model Reference Approach. New York: Marcel Dekker, 1979.

[4] Vas, P., " Sensorless Vector And Direct Torque Control " , Oxford University Press, 1998

[5] Bose, B. K., *Modern Power Electronics and AC Drives*, Pearson Publications, Delhi, India, 2003

[6] Hassan K. Khalil, Elias G. Strangas, and Sinisa Jurkovic, "*Speed Observer and Reduced Nonlinear Model for Sensorless Control of Induction Motors*" IEEE Transactions on Control Systems Technology, vol. 17, No. 2, March 2009, pp. 327–339

[7] A. Chikhi, M. Djarallah, K. Chikhi: A Comparative Study of Field-oriented Control andDirect-torque Control of Induction Motors using an Adaptive Flux Observer, Serbian Journal of Electrical Engineering Vol. 7, No. 1, May 2010, 41 – 55.

*[8]* Mabrouk J., Jarray K., Koubaa Y., Boussak M.; *A Luenberger State Observer for* Simultaneous Estimation of Speed and Rotor Resistance in sensorless Indirect Stator Flux Orientation Control of Induction Motor Drive, IJCSI International Journal of Computer Science Issues, 2011, 6(8), 3 p. 116-125.

[9] M. Hinkkanen et al., "Reduced-Order Flux Observers With Stator-Resistance Adaptation for Speed-Sensorless Induction Motor Drives", IEEE Trans. on Power Electronics, vol. 25, no.5, May 2010.

[10] Hinkkanen and J. Luomi, "Parameter sensitivity of full-order flux observers for induction motors," IEEE Trans. Ind. Appl., vol. 39, no. 4,pp. 1127–1135, Jul./Aug. 2003.

[11] B. Karanayil, M. F. Rahman, and C. Grantham, "Online stator and rotor resistance estimation scheme using artificial neural networks for vector controlled speed sensorless induction motor drive", IEEE Transaction on Industrial Electronics, vol. 54, no. 1, 2007, pp. 167-176.

[12] M. Rashed and A. F. Stronach, "A stable back-EMF MRAS-based sensorless low-speed induction motor drive insensitive to stator resistance variation," Proc. Inst. Elect. Eng.—Elect. Power Appl., vol. 151, no. 6,pp. 685–693, Nov. 2004.

[13] S. Maiti, C. Chakraborty, Y. Hori, and M. C. Ta, "Model reference adaptive controller-based rotor resistance and speed estimation techniques for vector controlled induction motor drive utilizing reactive power", IEEE Transaction on Industrial Electronics, vol. 55, no.2, pp. 594-601, Feb 2008.

[14] T. Orlowska-Kowalska, M. Dybkowski, "Stator Current-based MRAS Estimator for Wide Range Speed-Sensorless Induction Motor Drive", IEEE Trans. on Industrial Electronics, vol. 57, no. 4, pp. 1296-1308, Apr 2010.

[15] Zaky MS, Khater MM, Yasin HA, Shokralla SS, "Wide Speed range estimation with online parameter identification schemes of sensorless induction motor drives", IEEE Trans Ind Electron, vol.56, no. 5,1699–1707, May 2009.

[16] P. Bhatkar, Prabodh K. Khampriya,"MRAS Based Modified Speed Estimator for Speed Sensorless Field Oriented Controlled InductionMotor Drive Using MATLAB,"Journal of Electronics and Communication Engineering ISSN: 2278-2834,p- ISSN: 2278-8735,PP 63-69.