Design of a Novel Stator and Rotor Resistances Estimator for Sensorless Induction Motor Drives

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Abstract – In this paper, a novel model reference adaptive system (MRAS) is introduced for estimation the stator and rotor resistances and rotor speed. The presented MRAS is designed for simultaneous identification of the three quantities in order to save the cost of implementation and processes time. The Popov's criterion is used to design the adaptation mechanisms. The validation of the modified technique is tested through Matlab/ Simulink. The results evaluate the effectiveness of the suggested algorithm under load disturbance and parameters variation.

Keywords- Model Reference Adaptive System (MRAS), Induction Motor (IM), Speed Sensorless.

I. Introduction

Induction motors (IMs) are commonly used as variable speed drives in industry as a result of their advantages such as rugged construction and less maintenance [1]. Moreover, the accuracy of slip speed calculation is effect on the performance of the indirect field oriented control. The slip angle is calculated from the flux producing current component, the reference of torque, and rotor parameters of the machine under consideration [2-3]. For obtaining a precise rotor position, accurate values of rotor circuit parameters are required. Thus, to achieve a high dynamic performance, accurate values of machine parameters should be used in the controller.

The schemes of rotor flux estimation with constant parameters of induction machine model suffered from inaccuracy. This is attributed to the variation of machine parameters with temperature variations, frequency and magnetic saturation. A lot of algorithms have been presented to eliminate the effect of rotor resistance in IM drives [3]. The method presented in Refs. [4-5] was based on model reference adaptation of either flux or reactive power. Ref. [6] used the artificial injection signal for estimating the output signal variation. Ref. [7] detected the variation of rotor resistance using an adaptive feedback linearization control. Also, an Extended Kalman filter was used for estimating rotor resistance in Refs. [8-9]. From these algorithms, MRAS were the most common techniques that used for the identification processes; due to their relative simplicity and low computational effort [10-13].

In the most reported papers, the MRAS was used for rotor resistance estimation only or rotor speed only with or without stator resistance estimation. So, the aim of this paper is to save the cost of implementation and

processes time of speed estimators.
In this paper, a novel parallel MRAS is used to identify simultaneously the stator and rotor resistances for sensorless IM drives. The stability of the proposed scheme is derived based on Popov's criterion in order to design the adaptation mechanisms. For validation the proposed scheme at different operating conditions, the Matlab/Simulink package is used to test the control system. The simulation results prove the affectivity of the control system under load disturbance and/or parameters variation.

List of Symbols

V_{ds}, V_{qs} , i_{ds}, i_{qs}: The d-q axis stator voltage and current components (V);

i_{dr}, i_{qr}: The d-q axes rotor current components (A);

$i_{ds}^s, i_{qs}^s, i_{dr}^s, i_{qr}^s$: Stationary axes stator and rotor current components (A);

L_m: Magnetizing inductance (H);

L_r , L_s , L_{ls}, L_{lr}: Stator and rotor self-leakage and leakage inductance (H);

δ Leakage coefficient$\left(1 - \frac{L_m^2}{L_s L_r}\right)$;

T_l, T_e: Load and electromagnetic torques (Nm);

R_s, R_r: Stator and rotor resistances (Ω);

ω_e , ω_{sl} , ω_r, ω_r^*: Synchronous, slip, rotor speeds (rad/sec);

T_r: Rotor time constant, $T_r = \frac{L_r}{R_r}$;

J: Moment of inertia (kg.m^2);

$\lambda_{dr}^s, \lambda_{qr}^s$: Stationary axes rotor flux components (wb);

$\hat{\lambda}_{dr}^s, \hat{\lambda}_{qr}^s$: Stationary axes estimated rotor flux components (wb);

$\lambda_{dr}, \lambda_{qr}$: The d-q axes rotor flux components (wb);

$p = \frac{d}{dt}$: Differential operator;

P: No. of poles.

II. Induction Motor Model

The dynamic model of IM in $d^s - q^s$ stationary reference frame can be modified as follows [14]:

$$\frac{di_{qs}^s}{dt} = -\left(\frac{R_s}{L_s\delta} + \frac{R_rL_m^2}{L_sL_r^2\delta}\right)i_{qs}^s + \frac{R_rL_m}{L_sL_r^2\delta}\lambda_{qr}^s - \frac{L_m}{L_sL_r\delta}\omega_r\lambda_{dr}^s + \frac{1}{L_s\delta}V_{qs}^s \quad (1)$$

$$\frac{di_{ds}^s}{dt} = -\left(\frac{R_s}{L_s\delta} + \frac{R_rL_m^2}{L_sL_r^2\delta}\right)i_{ds}^s + \frac{L_m}{L_sL_r\delta}\omega_r\lambda_{qr}^s + \frac{R_rL_m}{L_sL_r^2\delta}\lambda_{dr}^s + \frac{1}{L_s\delta}V_{ds}^s \quad (2)$$

$$\frac{d\lambda_{qr}^s}{dt} = \frac{R_rL_m}{L_r}i_{qs}^s - \frac{R_r}{L_r}\lambda_{qr}^s + \omega_r\lambda_{dr}^s \quad (3)$$

$$\frac{d\lambda_{dr}^s}{dt} = \frac{R_rL_m}{L_r}i_{ds}^s - \omega_r\lambda_{qr}^s - \frac{R_r}{L_r}\lambda_{dr}^s \quad (4)$$

$$\frac{d\omega_r}{dt} = \frac{1}{J}(T_e - T_l) - \frac{f_b}{J}\omega_r \quad (5)$$

III. Vector Control of the Induction Motor

In vector control schemes, the condition of $\lambda_{qr} = 0$ is well pleased. Moreover, simplified indirect vector controller can be described for calculation the slip speed as follows:

$$\omega_{sl} = \omega_e - \omega_r \quad (6)$$

and aligning the rotor flux phasor λ_r on the d-axis as follows:

$$\lambda_{dr} = \lambda_r \quad (7)$$

$$\lambda_{qr} = 0 \quad (8)$$

Then, IM rotor model is presented as follows:

$$R_r i_{dr} + p\lambda_r = 0 \quad (9)$$

$$R_r i_{qr} + \omega_{sl}\lambda_r = 0 \quad (10)$$

$$i_{qr} = -\frac{L_m}{L_r}i_{qs} \quad (11)$$

$$i_{qr} = \frac{\lambda_r}{L_r} - \frac{L_m}{L_r}i_{ds} \quad (12)$$

$$\omega_{sl} = \frac{L_m}{T_r}\frac{i_{qs}}{\lambda_r} \quad (13)$$

$$p\lambda_r = \frac{1}{T_r}(-\lambda_r + L_m i_{ds}) \quad (14)$$

$$T_e = K_T i_{qs}\lambda_r \quad (15)$$

where: $K_T = \frac{3}{2}\frac{p}{2}\frac{L_m}{L_r}$ = torque constant.

Considering the command torque- and flux-producing current components, $i^*{}_{qs}$ and $i^*{}_{ds}$, then using them for calculation the command values of the rotor flux $\lambda^*{}_r$ and torque $T^*{}_e$ as follows:

$$i^*{}_{qs} = \frac{1}{K_T}\frac{T^*{}_e}{\lambda^*{}_r} \quad (16)$$

$$i^*{}_{ds} = \frac{1}{L_m}(1 + T_r p)\lambda^*{}_r \quad (17)$$

The slip speed command $\omega^*{}_{sl}$ is expressed as follows:

$$\omega^*{}_{sl} = \frac{L_m}{T_r}\frac{i^*{}_{qs}}{\lambda^*{}_r} \quad (18)$$

$$\theta_e^* = \int(\omega_r + \omega_{sl}^*)dt \quad (19)$$

IV. Modified MRAS

The IM model in the stationary $d^s - q^s$ reference frame can be expressed as follows:

Reference model (stator equation):

$$p\begin{bmatrix}\lambda_{dr}^s \\ \lambda_{qr}^s\end{bmatrix} = \frac{L_r}{L_m}\left(\begin{bmatrix}V_{ds}^s \\ V_{qs}^s\end{bmatrix} - \begin{bmatrix}R_s + \sigma\ L_s & 0 \\ 0 & R_s + \sigma\ (L_m + L_{ls})\end{bmatrix}\begin{bmatrix}i_{ds}^s \\ i_{qs}^s\end{bmatrix}\right) \quad (20)$$

Adjustable model (rotor equation):

$$p\begin{bmatrix}\hat{\lambda}_{dr}^s \\ \hat{\lambda}_{qr}^s\end{bmatrix} = \begin{bmatrix}-\frac{\hat{R}_r}{L_r} & -\hat{\omega}_r \\ \hat{\omega}_r & -\frac{\hat{R}_r}{L_r}\end{bmatrix}\begin{bmatrix}\hat{\lambda}_{dr}^s \\ \hat{\lambda}_{qr}^s\end{bmatrix} + \begin{bmatrix}\frac{L_m}{\hat{R}_r}i_{ds}^s \\ \frac{\hat{R}_r}{L_r}i_{qs}^s\end{bmatrix} \quad (21)$$

The modified MRAS has been shown in Fig. 1. In this figure, the rotor flux is estimated using the stator model (reference model), Eq. (20), and the rotor model, Eq. (21). The stator model as shown in Eq. (20) consists of the stator resistance. But the rotor model (adjustable model) consists of the rotor resistance and speed as shown in Eq. (21). The error between the two estimators is input to the suitable adjustable mechanism to estimate the stator resistance, $\hat{R}_s$, rotor resistance, $\hat{R}_r$ or speed $\hat{\omega}_r$. The estimation of the rotor resistance and rotor speed from one adjustable model is based on the fact of slow variation of the rotor resistance with temperature, and also using a different sample time for the two adaptation mechanisms. The stability and the adaptation laws for speed and stator and rotor resistances estimation have been deigned based on the Popov's criterion. Using Popov's criterion, the stability of MRAS can be analyzed as shown in Eqs (22-41). The state error equation can be written using Eqs. (20) and (21) as follows:

$$p\begin{bmatrix}\varepsilon_{dI} \\ \varepsilon_{qI}\end{bmatrix} = \begin{bmatrix}-\frac{R_r}{L_r} & -\omega_r \\ \omega_r & -\frac{R_r}{L_r}\end{bmatrix}\begin{bmatrix}\varepsilon_{dI} \\ \varepsilon_{qI}\end{bmatrix} + \frac{1}{L_r}(R_r - \hat{R}_r)\begin{bmatrix}\hat{\lambda}_{drI}^s - L_m i_{ds}^s \\ \hat{\lambda}_{qrI}^s - L_m i_{qs}^s\end{bmatrix} +$$
$$(\omega_r - \hat{\omega}_r)\begin{bmatrix}\hat{\lambda}_{drI}^s \\ \hat{\lambda}_{qrI}^s\end{bmatrix} + \frac{L_r}{L_m}(R_s - \hat{R}_s)\begin{bmatrix}i_{ds}^s \\ i_{qs}^s\end{bmatrix} \quad (22)$$

where;

$$p\begin{bmatrix}\varepsilon_{dI} \\ \varepsilon_{qI} \\ \varepsilon_{dv} \\ \varepsilon_{qv}\end{bmatrix} = \begin{bmatrix}-\frac{R_r}{L_r} & -\omega_r & 0 & 0 \\ \omega_r & -\frac{R_r}{L_r} & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0\end{bmatrix}\begin{bmatrix}\varepsilon_{dI} \\ \varepsilon_{qI} \\ \varepsilon_{dv} \\ \varepsilon_{qv}\end{bmatrix} - w_1 - w_2 - w_2 \quad (23)$$

$$w_1 = \frac{1}{L_r}(R_r - \hat{R}_r)\begin{bmatrix}\hat{\lambda}_{drI}^s - L_m i_{ds}^s \\ \hat{\lambda}_{qrI}^s - L_m i_{qs}^s\end{bmatrix} \quad (24)$$

$$w_1 = \begin{bmatrix} \frac{1}{L_r}\Delta R_r & 0 & -L_m & 0 \\ 0 & \frac{1}{L_r}\Delta R_r & 0 & -L_m \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} \hat{\lambda}_{drI}^s \\ \hat{\lambda}_{qrI}^s \\ i_{ds}^s \\ i_{qs}^s \end{bmatrix} \tag{25}$$

$$S = \int_0^{t_1} [\varepsilon]^T [W_1] dt \geq -\gamma_1^2 \text{ for all } t_1 \geq 0 \tag{26}$$

Substituting for $[W_1]$ and $[\varepsilon]^T$ in this inequality and using the definition of R_r, Popov's criterion for the present system becomes:

$$\int_0^{t_1} \left\{ [\varepsilon_{dI}\varepsilon_{qI}] \begin{bmatrix} \hat{\lambda}_{drI}^s - L_m i_{ds}^s \\ \hat{\lambda}_{qrI}^s - L_m i_{qs}^s \end{bmatrix} \frac{1}{L_r}\left(\hat{R}_r - \left[K_{PRr} + \right.\right.\right.$$

$$\left.\left.\left. \frac{K_{IRr}}{p} \right] e_{Rr} \right) \right\} dt \geq -\gamma_1^2 \quad \text{for all } t_1 \geq 0 \tag{27}$$

A solution to this inequality can be found through the following relation:

$$\int_0^{t_1} k(p.f(t))f(t)dt \geq -\frac{1}{2}k.f(0)^2, \quad k > 0 \tag{28}$$

$$\hat{R}_r = \left[K_{PRr} + \frac{K_{IRr}}{p}\right] \left([\varepsilon_{dI}\varepsilon_{qI}] \begin{bmatrix} \hat{\lambda}_{drI}^s - L_m i_{ds}^s \\ \hat{\lambda}_{qrI}^s - L_m i_{qs}^s \end{bmatrix} \right) \tag{29}$$

$$\hat{R}_r = \left(K_{pR_r} + \frac{K_{IR_r}}{p}\right)(\underline{\varepsilon}_I^T \hat{\underline{\lambda}}_{rI}^s - L_m.\underline{i}_s^s) \tag{30}$$

$$\hat{R}_r = \left(K_{pRr} + \frac{K_{IR_r}}{p}\right)\left([\varepsilon_{dI}\varepsilon_{qI}] \begin{bmatrix} \hat{\lambda}_{drI}^s - L_m i_{ds}^s \\ \hat{\lambda}_{qrI}^s - L_m i_{qs}^s \end{bmatrix} \right)$$

$$\hat{R}_r = \left[K_{PRr} + \frac{K_{IRr}}{p}\right]\left((\lambda_{drV} - \hat{\lambda}_{drI})(\hat{\lambda}_{drI}^s - L_m i_{ds}^s) + \right.$$

$$\left. (\lambda_{qrV} - \hat{\lambda}_{qrI})(\hat{\lambda}_{qrI}^s - L_m i_{qs}^s) \right) \tag{31}$$

where; $e_{Rr=}(\lambda_{drV} - \hat{\lambda}_{drI})(\hat{\lambda}_{drI}^s - L_m i_{ds}^s) + (\lambda_{qrV} - \hat{\lambda}_{qrI})(\hat{\lambda}_{qrI}^s - L_m i_{qs}^s)$ and K_{PRr} and K_{IRr} are the parameters of PI controller of an adaptation mechanism.

$$W_2 = \begin{bmatrix} -\Delta\omega_r \begin{bmatrix} 0 & -1 \\ 1 & 0 \end{bmatrix} & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \cdot \begin{bmatrix} \hat{\lambda}_{drI}^s \\ \hat{\lambda}_{qrI}^s \\ i_{ds}^s \\ i_{qs}^s \end{bmatrix} \tag{32}$$

$$W_2 = \begin{bmatrix} -\Delta\omega_r J & 0 \\ 0 & 0 \end{bmatrix} \cdot \begin{bmatrix} \hat{\underline{\lambda}}_{rI}^s \\ \underline{i}_s^s \end{bmatrix} \tag{33}$$

Popov's criterion requires that:

$$s = \int_0^{t_1} [\varepsilon]^T [W_2] dt \geq -\gamma_2^2 \text{ For all } t_1 \geq 0 \tag{34}$$

where;

γ_2^2 is a positive constant, $\underline{\varepsilon}^T = [\varepsilon_{dI}\varepsilon_{qI}\varepsilon_{dV}\varepsilon_{qV}] = [\underline{\varepsilon}_I^T \underline{\varepsilon}_V^T]$, $\Delta\omega_r = \omega_r - \hat{\omega}_r$ and $J = \begin{bmatrix} 0 & -1 \\ 1 & 0 \end{bmatrix}$.

$$S = -\int_0^{t_1} \Delta\omega_r(\underline{\varepsilon}_I^T.J.\hat{\underline{\lambda}}_{rI}^s)dt \geq -\gamma_2^2 \tag{35}$$

$$\hat{\omega}_r = \left(K_{p\omega} + \frac{K_{I\omega}}{p}\right)(\underline{\varepsilon}_I^T.J.\hat{\underline{\lambda}}_{rI}^s)$$

$$\hat{\omega}_r = \left(K_{p\omega} + \frac{K_{I\omega}}{p}\right)(\hat{\underline{\lambda}}_{rI}^s \times \hat{\underline{\lambda}}_{rV}^s) \tag{36}$$

$$\hat{\omega}_r = \left(K_{p\omega} + \frac{K_{I\omega}}{p}\right)e_\omega \tag{37}$$

where; $e_\omega = \hat{\lambda}_{drI}^s \hat{\lambda}_{qrV}^s - \hat{\lambda}_{qrI}^s \hat{\lambda}_{drV}^s$, $K_{P\omega}$ and $K_{I\omega}$ are the parameters of PI controller of an adaptation mechanism.

$$w_3 = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & \frac{-L_r}{L_m}\Delta R_s & 0 \\ 0 & 0 & 0 & \frac{-L_r}{L_m}\Delta R_s \end{bmatrix} \begin{bmatrix} \hat{\lambda}_{drI}^s \\ \hat{\lambda}_{qrI}^s \\ i_{ds}^s \\ i_{qs}^s \end{bmatrix} \tag{38}$$

$$W_3 = \begin{bmatrix} 0 & 0 \\ 0 & -\frac{L_r}{L_m}\Delta R_s I \end{bmatrix} \cdot \begin{bmatrix} \hat{\underline{\lambda}}_{rI}^s \\ \underline{i}_s^s \end{bmatrix} \tag{39}$$

$$S = \int_0^{t_1} [\varepsilon]^T [W_3] dt \geq -\gamma_3^2 \text{ for all } t_1 \geq 0$$

$$\hat{R}_s = \left(K_{pR_s} + \frac{K_{IR_s}}{p}\right)(-\underline{\varepsilon}_V^T.\underline{i}_s^s)$$

$$\hat{R}_s = \left(K_{pR_s} + \frac{K_{IR_s}}{p}\right)[\underline{i}_s^s \bullet (\hat{\underline{\lambda}}_{rV}^s - \hat{\underline{\lambda}}_{rI}^s)]$$

$$\hat{R}_s = \left(K_{pR_s} + \frac{K_{IR_s}}{p}\right)e_{Rs} \tag{41}$$

where; $e_{Rs} = \hat{i}_{ds}^s(\hat{\lambda}_{drV}^s - \hat{\lambda}_{drI}^s) + i_{qs}^s(\hat{\lambda}_{qrV}^s - \hat{\lambda}_{qrI}^s)$, $I = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$, K_{PRs} and K_{IRs} are the parameters of PI controller of an adaptation mechanism.

V. Proposed Sensorless Vector Controlled Induction Motor Drive

Figure 2 displays the scheme of the suggested control system for the sensorless indirect vector-controlled IM drive including the estimation of the rotor resistance and stator resistance. The block diagram involves the induction motor model, a hysteresis current controlled PWM, inverter, the designed vector control with a co-ordinate transformation and closed loop speed controller. Moreover, figure 2 shows the adaptive stator-rotor resistance and motor speed estimator. The estimation process of the stator and rotor resistances has been designed to run in parallel at each time step in the implementation time.
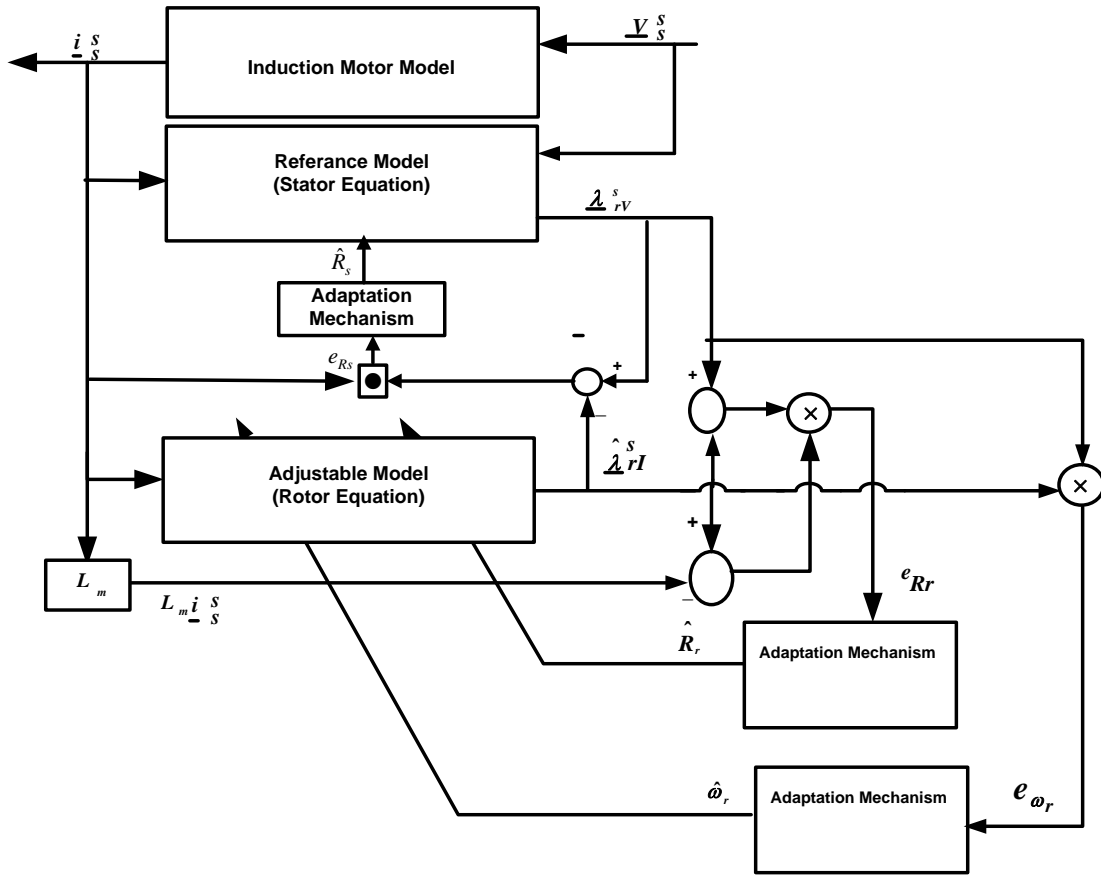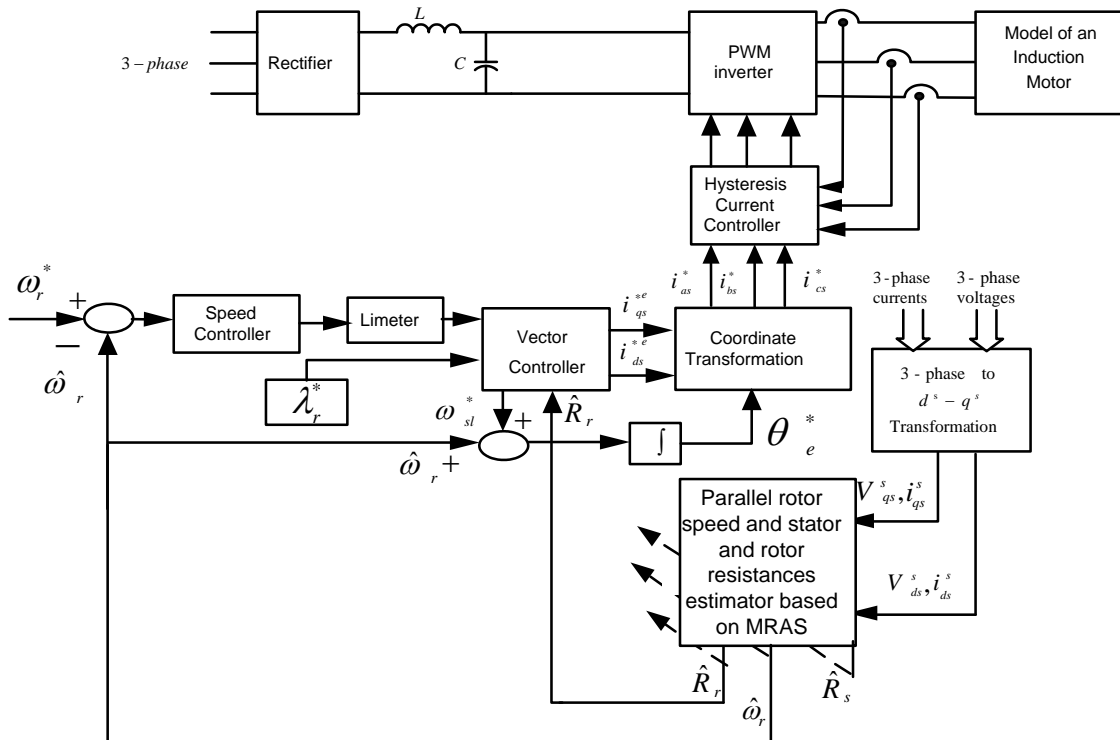
Figure 1: Structure of MRAS.

Figure 2: The block diagram of the parallel MRAS for sensorless IM drive.

VI. Simulation Results and Discussion

In order to validate the proposed control scheme, a 3.8 HP induction motor with four poles has been tested considering various operating conditions. The nominal parameters and specifications of induction motor have been itemized in table 1. The Matlab/ Simulink is utilized for evaluating proposed control system.

Table 1: Parameters and data specifications of the induction motor

Rated power (HP)	3.8	Rated voltage (V)	380
Rated current (A)	8	Rated frequency (Hz)	50
Rr (Ω)	1.009	Rs (Ω)	1.725
Lr (H)	0.1473	Ls (H)	0.1473
Lm (H)	0.1271	Rated rotor flux, (wb)	0.735
J (kg. m2)	0.0400	Rated speed (rpm)	1450

The influence of variation of the rotor resistance in the IM drive is shown in Fig. 3. In this case of study, the transient performance is examined for step change of the rotor resistance when the motor is running at very low speed of 10 rad/sec at nominal load torque. Figures 3a-3f show the dynamic response when the rotor resistance is increased by 50 % from its nominal value at t = 5 sec. From Figs. 3b-3f, it is seen that, the estimated stator resistance, estimated motor speed, speed error, motor torque, and $d-q$ axes rotor flux components are

equal their command values during the rotor resistance variation.

Figure 4 shows the performance of IM drive at rated speed of 150 rad/sec, rated load and 50% increment of rotor resistance. The estimated rotor and stator resistances, estimated speed, speed error, motor torque, and $d-q$ axes rotor flux components are all shown in Figs. 4a-4f. The figure shows a large spike for a very short time in estimated torque, the reasons of this large spike may be because the step variation in the rotor resistance at high speed reference speed.

The sensorless IM drive system has been tested with step change in the load torque from 10 N.m to 20 N.m. Figure 5 shows the drive response when the rotor resistance is increased by a 150 % of its nominal value at command speed of 100 rad/sec. This figure shows that, the actual and estimated speed has the same track and the d-axis rotor flux component is equal to its command value. Also, the q-axis rotor flux component is equal to zero that satisfies the vector control principles.

In a different manner, a ramp variation of the rotor resistance from its nominal value to 150% of its nominal value is assumed as shown in Fig. 6. This figure shows the results at speed of 150 rad/sec. While, Figs. 7 show the performance of the sensorless IM drive at different rotor speed of 100 rad/sec respectively with the ramp variation of rotor resistance.
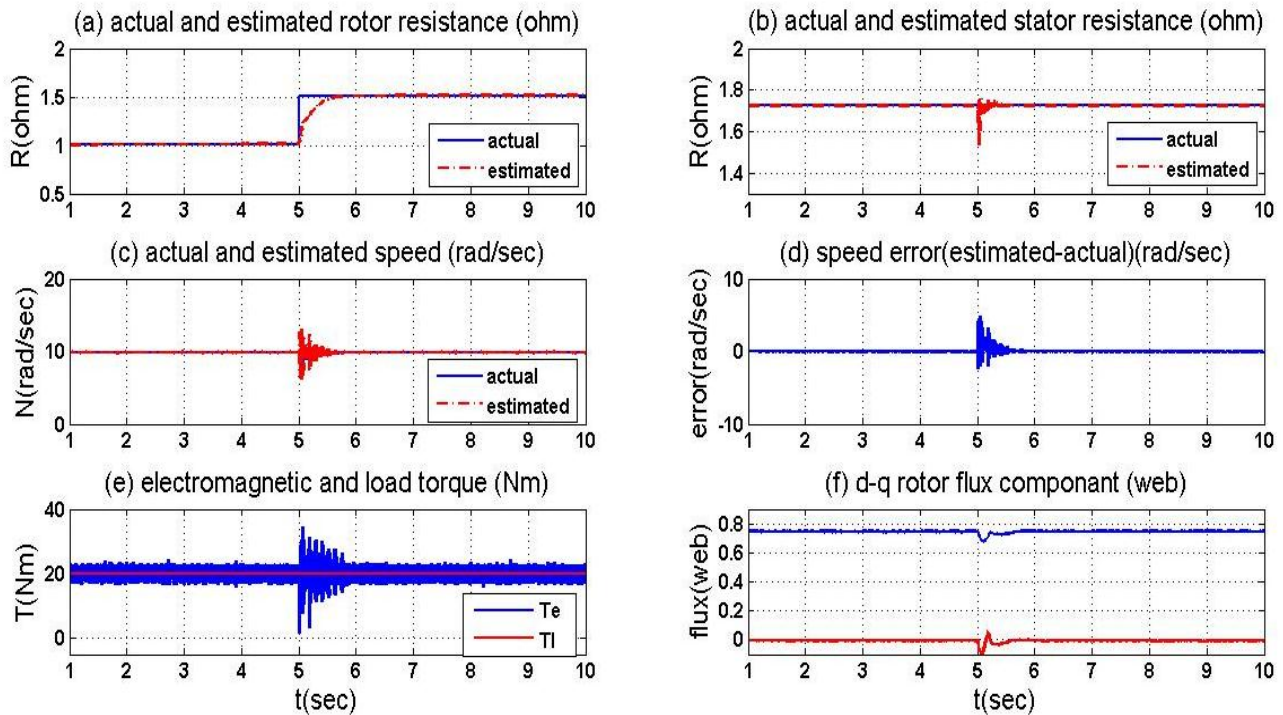

Figure 3: The effect of rotor resistance variation on the motor drive performance at very low speed.
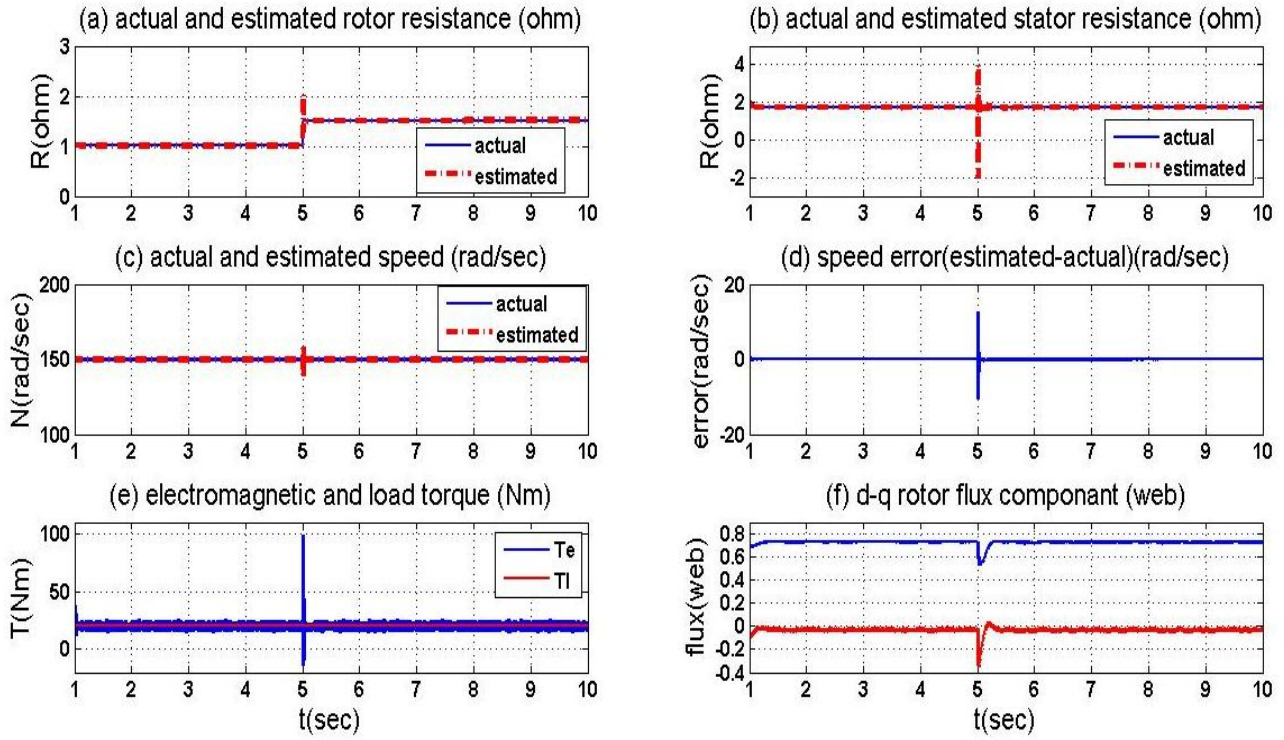
Figure 4: Estimation of rotor resistance and speed for induction motor drive performance at high speed 150 rad/sec.
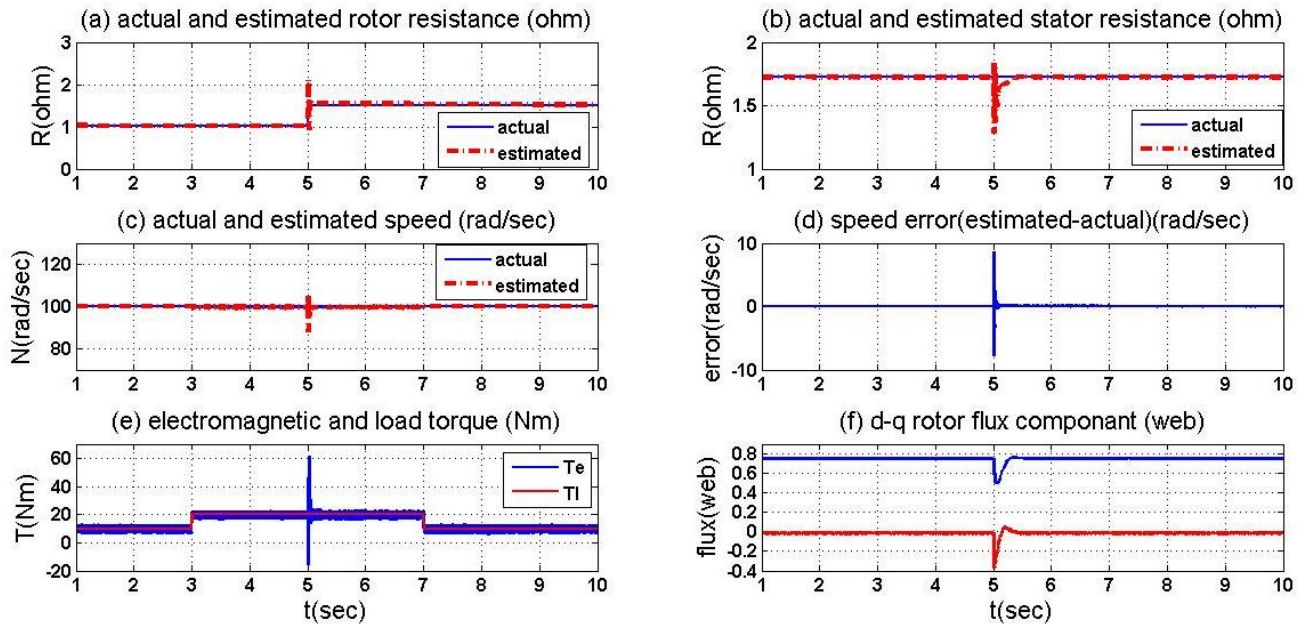

Figure 5: Performance of the proposed sensorless drive system for load torque disturbance at 100 rad/sec.
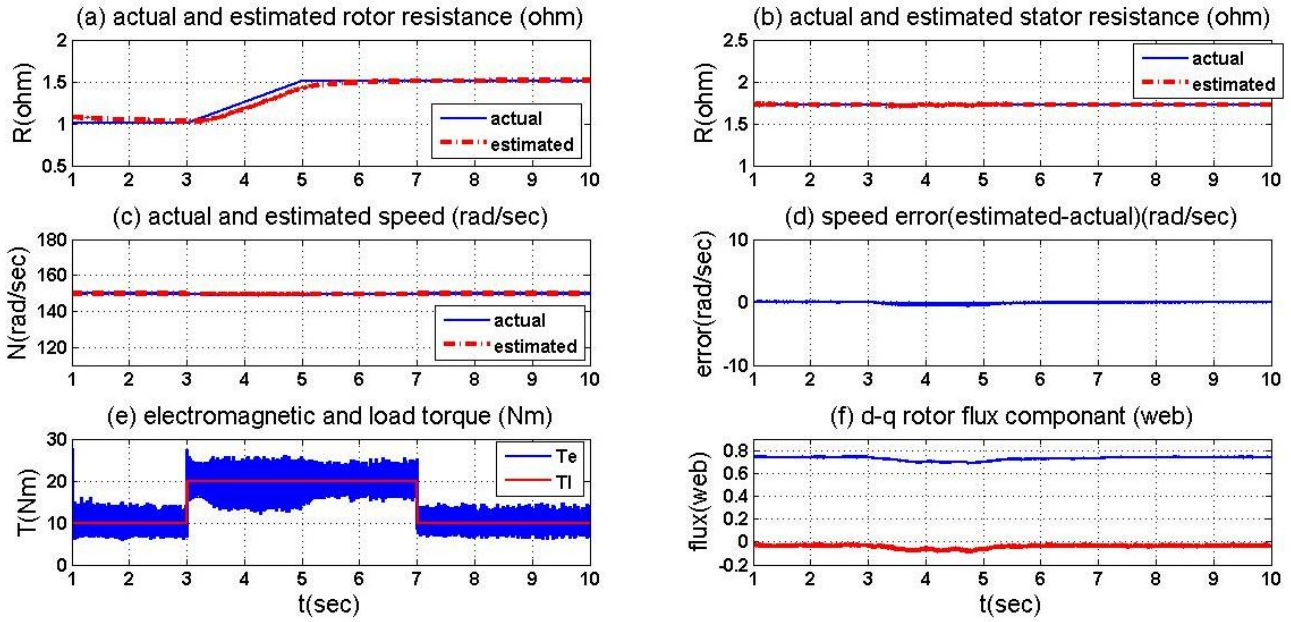
Figure 6: Performance of the proposed sensorless drive system for load torque disturbance at high speed of 150 rad/sec.
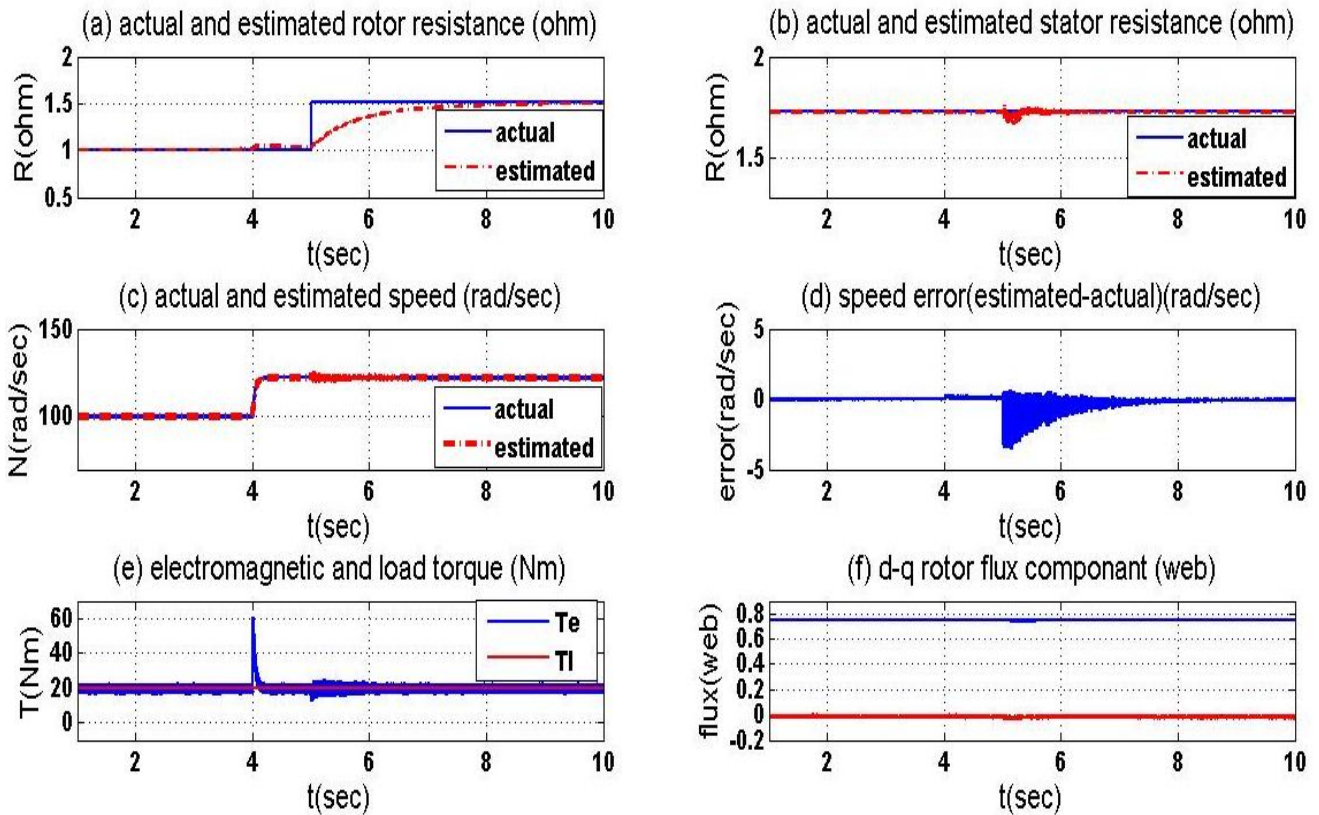

Figure 7: Performance of the proposed sensorless drive system with step increase
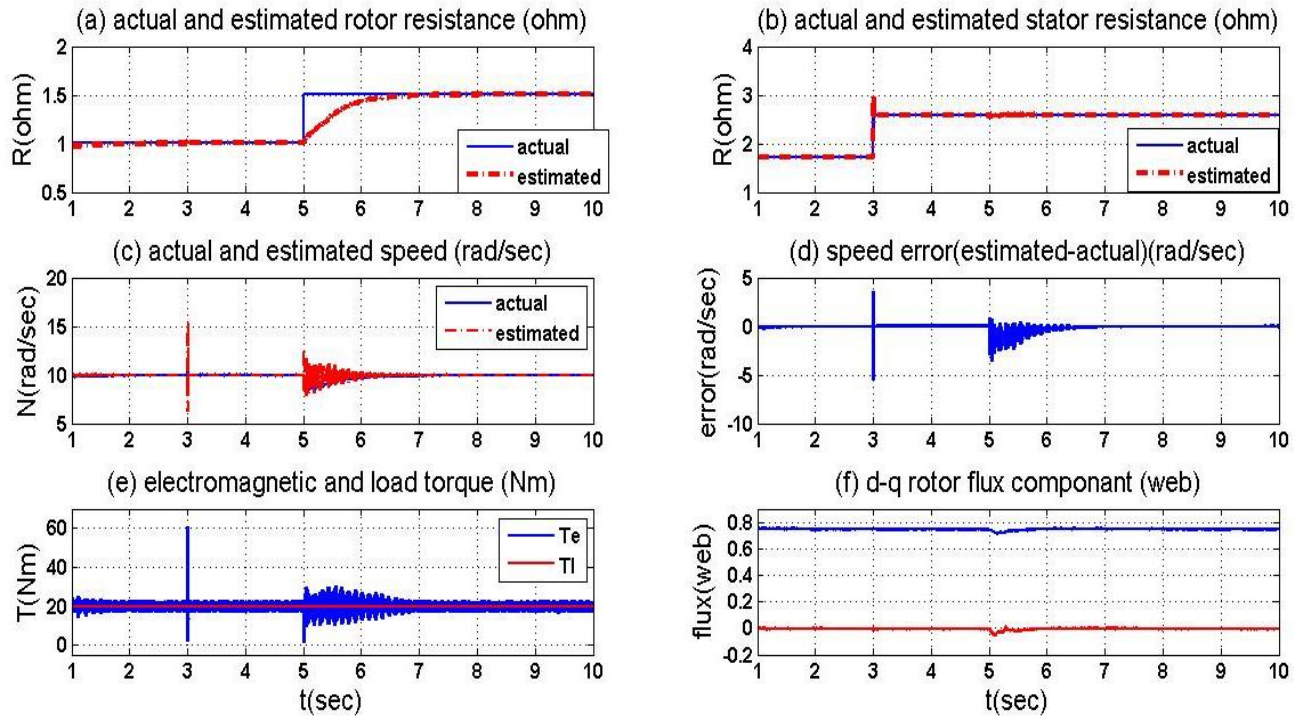in the rotor resistance (speed = 100 rad/sec.)

Figure 8: Motor performance with step increase in the stator and rotor resistance
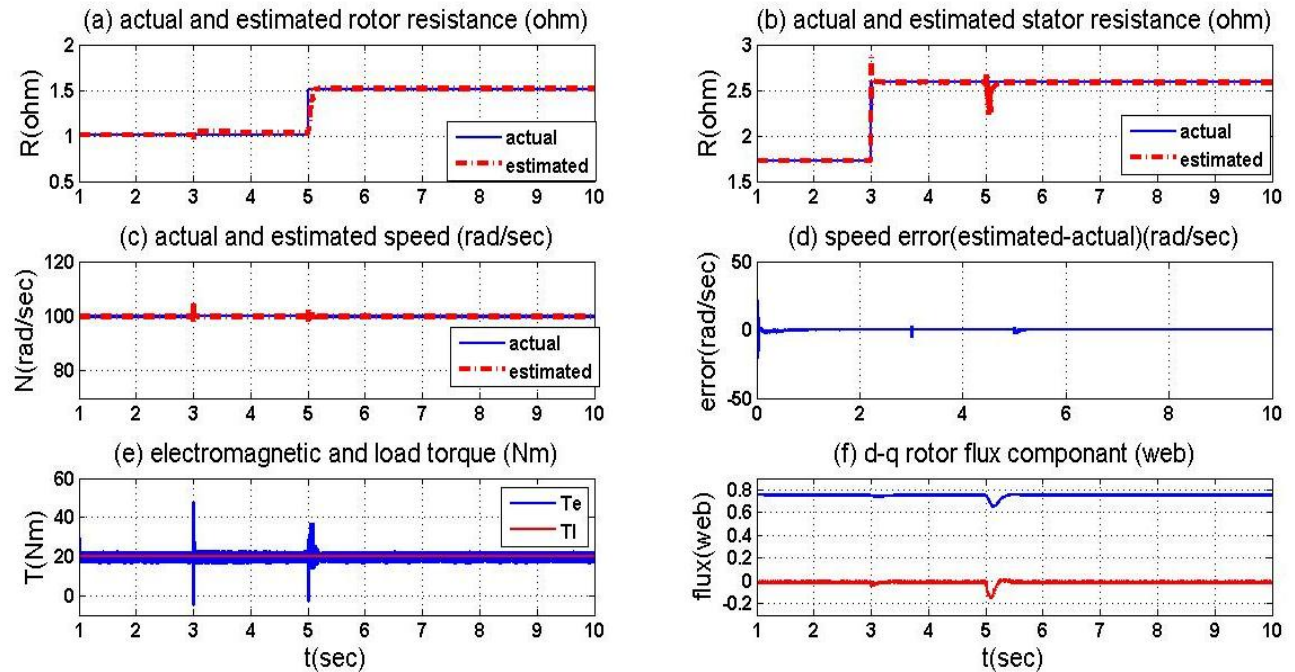at very low speed.

Figure 9: Motor performance with step increase in the stator and rotor resistance
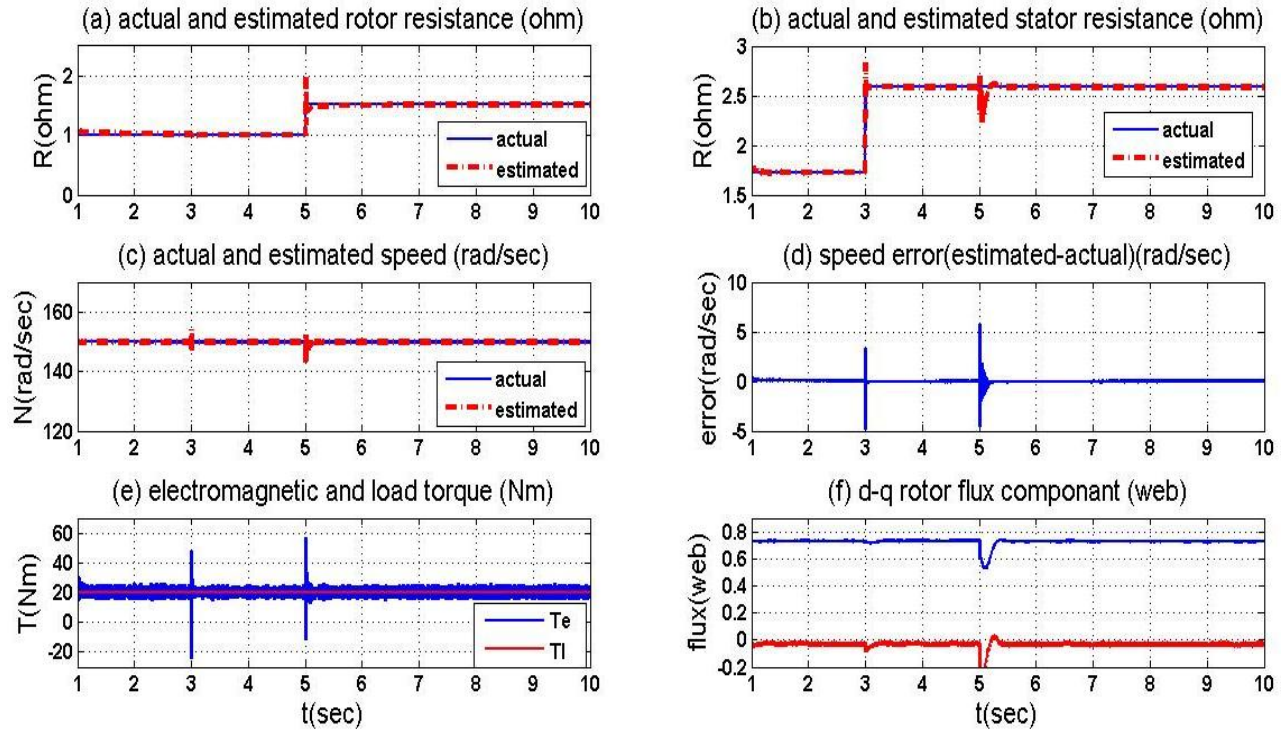at low speed.

Figure 10: Motor performance with step increase in the stator and rotor resistance
at high speed.

The variation in stator resistance will be done in parallel with the rotor resistance to ensure the stability of the drive system. Figures 8- 10 show the variation of stator and rotor resistance by a 150% of its nominal values. The motor speed in these cases is kept constant at 10 rad/sec, 100 rad/sec and 150 rad/sec respectively. From these figures, a good dynamic performance and an accurate estimation of rotor resistance and rotor speed have been achieved.

VII. Conclusions

This paper presented a novel MRAS for estimation stator, rotor resistances and rotor speed for sensorless IM drive simultaneously. This algorithm achieves a high-precise control in a wide range of motor speed and saves the implementation cost and processes time. Moreover, the stability of the control scheme is derived using Popov's criterion to obtain the adaptation mechanisms. Simulation tests are performed for investigation the performance of presented scheme under different operating conditions. The simulation results show that, the dynamic performance of the presented drive is satisfactory at very low speed as well as high speed operation under the load torque disturbance.

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الملخص العربي

ملخص- يهدف البحث إلى تقديم طريقة جديدة معتمداً على النموذج المرجعي للنظام الملائم MODEL REFERENCE ADAPTIVE SYSTEM (MRAS) لحساب وتقدير قيم كل من مقاومة العضو الدوار للمحرك الحثي ومقاومة العضو الثابت وسرعة المحرك بالتوازي وفي ذات الوقت اذناء تشغيل المحرك On-line simultaneous Estimation. تم تقديم هذه الطريقة لاستخدامها في التحكم الإتجاهى للمحرك بدون استخدام حساسات للسرعة وتوفيرا لوقت تنفيذ وحساب وحل المعادلات الرياضية وللحصول على دقة عالية في التحكم. وتم عرض نتائج نظرية باستخدام برامج المحاكاه لتوضيح مدى قدرة الطريقة المقترحة وكفائتها. وقد برهنت النتائج المعروضة على أن خواص نظام المحرك ممتازة وهذا يؤكد قدرة الطريقة على تحقيق الأغراض المطلوبة.