Squirrel Cage Induction Motor (SCIM) Rotor Flux Estimation and Observer Using Multivariable Sliding Mode Control (MSMC)

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Abstract: This paper proposes a multivariable sliding mode control (MSMC) based in rotor flux estimation and observer methods for squirrel cage induction motor (SCIM).
The principle of sliding mode control (SMC) adjustment can also be applied to multivariable systems. In this case, for each control quantity, there is a control member who switches the latter quickly between a maximum value and a minimum value, thus causing the sliding mode to appear. This article will discuss sliding mode tuning of multivariable systems, highlighting issues that arise in relation to mono-variable systems studied so far. In this paper, we will establish the general relationships, where we introduce the regulators of multivariable systems. To describe the behavior in sliding mode, we will call or equivalent control vector, at the end of this article we will introduce a rotor flux observer to improve the results obtained. The work is developed with a 2-level voltage source inverter. The simulation results are carried out to verify and validate the multivariable sliding mode control method proposed based rotor flux estimation and observer scheme

Keywords: SMC, MSMC, SCIM, Flux Estimation, Flux Observer

1. INTRODUCTION

The introduction section must contain theory related to the paper topic along with state of art study and well referenced citations. Make this section as informative as possible to justify the work and situate it with respect to the literature.

Direct current motors (DCM) have been widely used in areas requiring variable speed and position drives, due to the simplicity of controlling flux and torque from excitation current and armature current [1]. They operate - naturally - at maximum torque: the inductor field and the induced field are perpendicular thanks to the brush-collector system, which is not the case for other machines where the power engineer develops full ingenuity to obtain the same situation using power electronics and digital techniques [1], [2].

Currently, the use of alternating current motors, more particularly squirrel cage induction motors (SICM), is more and more frequent, because these machines are characterized by their robustness and longevity, although these require structures internal and more complex control strategies. In order to obtain performances similar to those of the DCM with cage motors which can be based on wound rotor asynchronous motors as well as on synchronous machines, it was necessary to separate the flow control and the control of the current generating the electromagnetic torque to introduce vector control (FOC) based on PI regulators [3], [4], [5].

Classic control techniques (PI regulators for example) require perfect knowledge of the model of the system to be adjusted. These approaches lead to control laws whose performance is strongly linked to the fidelity of the dynamic model used to describe the behavior of the system. Modeling errors or parametric variations of the system can deteriorate the performance of the adjustment since they contribute directly to the calculation of the control.

In order to solve such problems, the proposal of new control techniques is essential [5], [6], [7], [8].

Another type of modern controls that has attracted many researchers in recent years is sliding mode control. The recent interest in this control is mainly due to the availability of switches with high switching frequency and high-performance microprocessors [9], [10].

The sliding mode is a particular mode of operation of systems with variable structure [11]. In sliding mode tuning, the control switches between two different values following the sign of a switching function (often called switching or sliding surface) defined in the system state space. This is introduced in order to obtain better stability and high precision than those generally obtained by conventional regulators. Several approaches exist for the choice of the sliding surface. In our work, we are interested in the study of an approach which considers a nonlinear surface, the synthesis of which is based on the stability theory of LYAPUNOV [12].

The sliding mode control (SMC) method has interesting advantages: robustness to disturbances and low sensitivity of the system to parameter variations [13], [14]. Sliding mode control can be used for estimation and observation of rotor flux of SCIM using the equivalent control signal. Chatter phenomena exist in traditional sliding mode control [15].

This article proposes rotor flux estimation and observation method based on multivariable sliding mode control (MSMC) of SCIM, this method consists of dividing the system into two subsystems. The rotor flux of the motor can be estimated using the smooth equivalent control signal from the observer and the use of a necessary observer to eliminate the disturbances on the different variables and to obtain a high performance of the proposed control. The simulation results validate the proposed strategy.

2. DYNAMIC MODEL OF SQUIRREL CAGE INDUCTION MOTOR (SCIM)

The mathematical model of a SCIM system in the mobile frame (d-q) can be described as follows [3]; whose state variables are the stator currents and the rotor fluxes and the mechanical rotation speed.

$$\begin{cases} \frac{dI_{Sd}}{dt} = \frac{1}{L_S.\sigma}\left(-\left(R_S + \frac{R_R.M^2}{L_R{}^2}\right)I_{Sd} + \omega_S.I_{Sq} + \frac{R_R.M}{L_R{}^2}.\phi_{Rd} + V_{Sd}\right) \\ \frac{dI_{Sq}}{dt} = \frac{1}{L_S.\sigma}\left(-\omega_S.L_S.\sigma.I_{Sd} - R_S.I_{Sq} - \omega_S.\frac{M}{L_R}.\phi_{Rd} + V_{Sq}\right) \\ \frac{d\phi_{Rd}}{dt} = \frac{R_R.M}{L_R}.I_{Sd} - \frac{R_R}{L_R}.\phi_{Rd} \\ \frac{d\omega_m}{dt} = \frac{M.P^2}{L_R.J}.\phi_{Rd}.I_{Sq} - \frac{f}{J}.\omega_m - \frac{P}{J}.T_R \end{cases} \quad (1)$$

3. A MULTIVARIABLE SLIDING MODE CONTROL (MSMC)

A. Concept of multivariable control

$$S(\omega_m) = \left(\frac{\partial}{\partial t} + \lambda\right)^{r-1}.e(x) \quad (2)$$

$$\dot{S}(x) = \frac{\partial S}{\partial t} = \frac{\partial S}{\partial X}.\frac{\partial X}{\partial t} = \frac{\partial S}{\partial X}.\dot{X} \quad (3)$$

$$\dot{S}(x) = \frac{\partial S}{\partial t}.\left[A.\dot{X} + B.u\right] = F(x,t) + D.U \quad (4)$$

By replacing U with $U^* = U_{eq} + U_n$ we find:

$$\dot{S}(x) = \frac{\partial S}{\partial t}.\left[A.\dot{X} + B.u\right] = F(x,t) + D.U_{eq} + D.U_n \quad (5)$$

During the sliding mode and the steady state we have $S(x) = 0$ and consequently $\dot{S}(x) = 0$ and $U_n = 0$ So $F(x,t) + D.U_{eq} = 0$ where we get from U_{eq}

$$U_{eq} = -D^{-1}.F(x,t) \quad (6)$$

During convergence mode, the condition $\dot{S}(x).S(x) < 0$ must be verified. By replacing the formula of U_{eq} in equation (4), we find:

$$\dot{S}(x) = D.U_n \quad (7)$$

So we have:

$$U_n = -inv(D).K.Sign(S(x)) \quad (8)$$

B. adjustment surface of the S1 system

The relative degree rωm is equal to one; hence the regulation surfaces have the form:

$$S_1(x) = \begin{pmatrix} \omega_m^* - \omega_m \\ \phi_{Rd}^* - \phi_{Rd} \\ \phi_{Rq}^* - \phi_{Rq} \end{pmatrix} \quad (9)$$

The derivatives of the surfaces are:

$$\dot{S}_1(x) = \begin{pmatrix} \dot{\omega}_m^* - \dot{\omega}_m \\ \dot{\phi}_{Rd}^* - \dot{\phi}_{Rd} \\ \dot{\phi}_{Rq}^* - \dot{\phi}_{Rq} \end{pmatrix} \quad (10)$$

$$\dot{S}_1(x) = \begin{pmatrix} \dot{\omega}_m^* - \dot{\omega}_m \\ \dot{\phi}_{Rd}^* - \dot{\phi}_{Rd} \\ \dot{\phi}_{Rq}^* - \dot{\phi}_{Rq} \end{pmatrix} = \begin{pmatrix} \dot{\omega}_m^* - \frac{P^2.M}{J.L_R}.\phi_{Rd}.I_{Sq} + \frac{P^2.M}{J.L_R}.\phi_{Rq}.I_{Sd} + \\ + \frac{f}{J}.\omega_m + \frac{P}{J}.t_R \\ \dot{\phi}_{Rd}^* + \frac{R_R}{L_R}.\phi_{Rd} - \frac{R_R.M}{L_R}.I_{Sd} - \\ - \omega_R.\phi_{Rq} \\ \dot{\phi}_{Rq}^* + \frac{R_R}{L_R}.\phi_{Rq} - \frac{R_R.M}{L_R}.I_{Sq} + \omega_R.\phi_{Rq} \end{pmatrix} \quad (11)$$

$$\dot{S}_1(x)=\begin{pmatrix}\dot{\omega}_m^*+\frac{f}{J}.\omega_m+\frac{P}{J}.t_R\\ \dot{\phi}_{Rd}^*+\frac{R_R.M}{L_R}.\phi_{Rd}\\ \dot{\phi}_{Rq}^*+\frac{R_R.M}{L_R}.\phi_{Rq}\end{pmatrix}+ \tag{12}$$

$$+\begin{pmatrix}\frac{P^2.M}{J.L_R}.\phi_{Rq} & -\frac{P^2.M}{J.L_R}.\phi_{Rd} & 0\\ -\frac{R_R.M}{L_R} & 0 & -\phi_{Rq}\\ 0 & -\frac{R_R.M}{L_R} & \phi_{Rd}\end{pmatrix}.\begin{pmatrix}I_{Sd}\\ I_{Sq}\\ \omega_R\end{pmatrix}$$

Replacing, I_{Sd}, I_{Sq} and ω_R by $I_{Sd}^*=I_{Sdeq}+I_{Sdn}$, $I_{Sq}^*=I_{Sqeq}+I_{Sqn}$ and $\omega_R^*=\omega_{Re\,q}+\omega_{Rn}$ we find :

$$\dot{S}_1(x)=\begin{pmatrix}\dot{\omega}_m^*+\frac{f}{J}.\omega_m+\frac{P}{J}.T_R\\ \dot{\phi}_{Rd}^*+\frac{R_R.M}{L_R}.\phi_{Rd}\\ \dot{\phi}_{Rq}^*+\frac{R_R.M}{L_R}.\phi_{Rq}\end{pmatrix}+$$

$$+\begin{pmatrix}\frac{P^2.M}{J.L_R}.\phi_{Rq} & -\frac{P^2.M}{J.L_R}.\phi_{Rd} & 0\\ -\frac{R_R.M}{L_R} & 0 & -\phi_{Rq}\\ 0 & -\frac{R_R.M}{L_R} & \phi_{Rd}\end{pmatrix}\times\begin{pmatrix}I_{Sdeq}+I_{Sdn}\\ I_{Sqeq}+I_{Sqn}\\ \omega_{Re\,q}+\omega_{Rn}\end{pmatrix} \tag{13}$$

$$\begin{pmatrix}I_{Sdeq}\\ I_{Sqeq}\\ \omega_{Re\,q}\end{pmatrix}=-\begin{pmatrix}\frac{P^2.M}{J.L_R}.\phi_{Rq} & -\frac{P^2.M}{J.L_R}.\phi_{Rd} & 0\\ -\frac{R_R.M}{L_R} & 0 & -\phi_{Rq}\\ 0 & -\frac{R_R.M}{L_R} & \phi_{Rd}\end{pmatrix}^{-1}\times \tag{14}$$

$$\times\begin{pmatrix}\dot{\omega}_m^*+\frac{f}{J}.\omega_m+\frac{P}{J}.t_R\\ \dot{\phi}_{Rd}^*+\frac{R_R}{L_R}.\phi_{Rd}\\ \dot{\phi}_{Rq}^*+\frac{R_R}{L_R}.\phi_{Rq}\end{pmatrix}$$

$$\begin{pmatrix}I_{Sdn}\\ I_{Sdn}\\ \omega_{Rn}\end{pmatrix}=-\begin{pmatrix}\frac{P^2.M}{J.L_R}.\phi_{Rq} & -\frac{P^2.M}{J.L_R}.\phi_{Rd} & 0\\ -\frac{R_R.M}{L_R} & 0 & -\phi_{Rq}\\ 0 & -\frac{R_R.M}{L_R} & \phi_{Rd}\end{pmatrix}^{-1}\times \tag{15}$$

$$\times\begin{pmatrix}K_{fd} & 0 & 0\\ 0 & K_{fq} & 0\\ 0 & 0 & K_\omega\end{pmatrix}.Sign(S_1(x))$$

C. adjustment surface of the S2 system

$$S_2(x)=\begin{pmatrix}I_{Sd}^*-I_{Sd}\\ I_{Sq}^*-I_{Sq}\end{pmatrix} \tag{16}$$

The derivatives of the surfaces are:

$$\dot{S}_2(x)=\begin{pmatrix}\dot{I}_{Sd}^*-\dot{I}_{Sd}\\ \dot{I}_{Sq}^*-\dot{I}_{Sq}\end{pmatrix} \tag{17}$$

$$\dot{S}_2(x)=\begin{pmatrix}\dot{I}_{Sd}^*+\frac{1}{\sigma.L_S}.\left(R_S+\frac{R_R.M^2}{L_R^{\,2}}\right).I_{Sd}-\omega_S.I_{Sq}-\\ -\frac{R_R.M}{\sigma.L_S.L_R^{\,2}}.\phi_{Rd}-\frac{M.\omega_m}{\sigma.L_S.L_R}.\phi_{Rq}-\frac{1}{\sigma.L_S}.V_{Sd}\\ \dot{I}_{Sq}^*+\omega_S.I_{Sd}+\frac{1}{\sigma.L_S}.\left(R_S+\frac{R_R.M^2}{L_R^{\,2}}\right).I_{Sq}+\\ +\frac{M.\omega_m}{\sigma.L_S.L_R}.\phi_{Rd}-\frac{M.R_R}{\sigma.L_S.L_R^{\,2}}.\phi_{Rq}-\frac{1}{\sigma.L_S}.V_{Sq}\end{pmatrix} \tag{18}$$

Replacing, V_{Sd} , V_{Sq} by $V_{Sd}^*=V_{Sdeq}+V_{Sdn}$,

$$\dot{S}_2(x)=\begin{pmatrix}\dot{I}_{Sd}^*+\frac{1}{\sigma.L_S}\left(R_S+\frac{R_R.M^2}{L_R^{\,2}}\right).I_{Sd}^*-\omega_S.I_{Sq}^*-\\ -\frac{M.R_R}{\sigma.L_S.L_R^{\,2}}.\hat{\phi}_{Rd}-\frac{M.\omega_m}{\sigma.L_S.L_R}.\hat{\phi}_{Rq}\\ \dot{I}_{Sq}^*+\omega_S.I_{Sd}^*+\frac{1}{\sigma.L_S}\left(R_S+\frac{R_R.M^2}{L_R^{\,2}}\right).I_{Sq}^*+\\ +\frac{M.\omega_m}{\sigma.L_S.L_R}.\hat{\phi}_{Rd}-\frac{M.R_R}{\sigma.L_S.L_R^{\,2}}.\hat{\phi}_{Rq}\end{pmatrix}+\begin{pmatrix}-\frac{1}{\sigma.L_S} & 0\\ 0 & -\frac{1}{\sigma.L_S}\end{pmatrix}\times$$

$$\times\begin{pmatrix}V_{Sdeq}+V_{Sdn}\\ V_{Sqeq}+V_{Sqn}\end{pmatrix} \tag{19}$$

$V_{Sq}^{*} = V_{Sqeq} + V_{Sqn}$ we find

$$\begin{pmatrix} V_{Sdeq} \\ V_{Sqeq} \end{pmatrix} = -\begin{pmatrix} -\frac{1}{\sigma.L_S} & 0 \\ 0 & -\frac{1}{\sigma.L_S} \end{pmatrix}^{-1} \times$$

$$\times . \begin{pmatrix} \overset{\bullet}{I}{}^{*}_{Sd} + \frac{1}{\sigma.L_S}\left(R_S + \frac{R_R.M^2}{L_R{}^2}\right).I_{Sd}^{*} - \omega_S.I_{Sq}^{*} - \\ -\frac{M.R_R}{\sigma.L_S.L_R{}^2}.\hat{\phi}_{Rd} - \frac{M.\omega_m}{\sigma.L_S.L_R}.\hat{\phi}_{Rq} \\ \overset{\bullet}{I}{}^{*}_{Sq} + \omega_S.I_{Sd}^{*} + \frac{1}{\sigma.L_S}\left(R_S + \frac{R_R.M^2}{L_R{}^2}\right).I_{Sq}^{*} + \\ + \frac{M.\omega_m}{\sigma.L_S.L_R}.\hat{\phi}_{Rd} - \frac{M.R_R}{\sigma.L_S.L_R{}^2}.\hat{\phi}_{Rq} \end{pmatrix} \quad (20)$$

$$\begin{pmatrix} V_{Sdn} \\ V_{Sqn} \end{pmatrix} = -\begin{pmatrix} -\frac{1}{\sigma.L_S} & 0 \\ 0 & -\frac{1}{\sigma.L_S} \end{pmatrix}^{-1} \times \quad (21)$$

$$\times . \begin{pmatrix} K_d & 0 \\ 0 & K_q \end{pmatrix} .Sign(S_2(x))$$

D. Diagram of a multivariable sliding mode control with rotor flux estimation

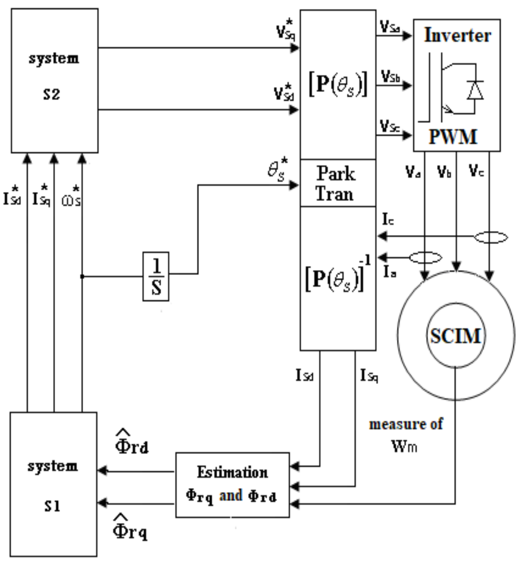

Fig. 1 Multivariable sliding mode control diagrams of Squirrel Cage Induction Motor (SCIM) (Flux estimation).

E. Simulation Results.

For verifying the proposed rotor flux observer of the SCIM, the simulations are carried out. SCIM is considered in the simulation and parameters as given in Appendix (Table 1).
The multivariable sliding mode control (MSMC) has been implemented in MATLAB/SIMULINK.
The multivariable sliding mode control (MSMC) algorithm is compared using the same rotor speed reference command.
The simulation results are shown in Figs 2-7 (stator currents direct and quadrature, rotor flux direct and quadrature, Speed of SCIM and Electromagnetic torque of SCIM.
The SCIM runs in speed regulation at 150 rpm between t =0 until t =2s, it undergoes a disturbance presented by the torque resisting at t =1s, the speed reference will change by 150 rpm a - 150 rpm. The current Isq perfectly follows its reference Isq* throughout the test. The current Φrd remains constant and equal to its reference value (Φr =1 w). The flux Φrq is simulated all the time, which proves the effectiveness of the control based on the rotor flux estimator.

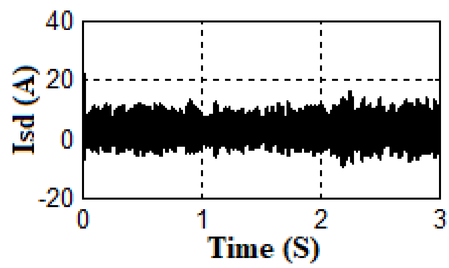

Fig. 2Stator current direct.

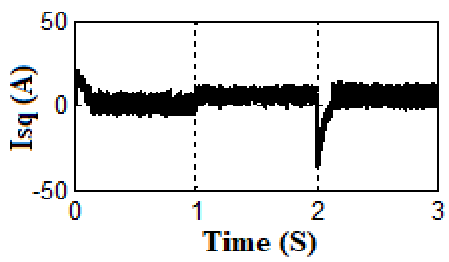

Fig. 3 Stator current quadrature.

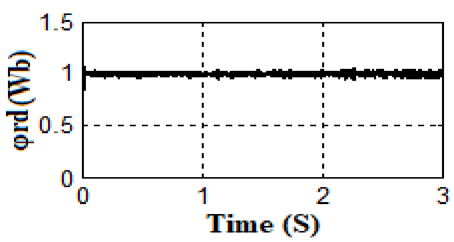

Fig. 4 Rotor flux direct.

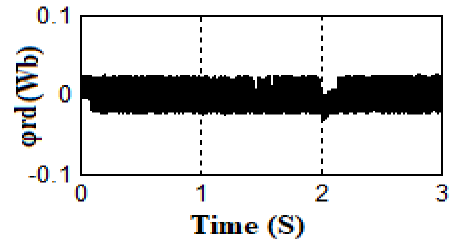

Fig. 5 Rotor flux quadrature.

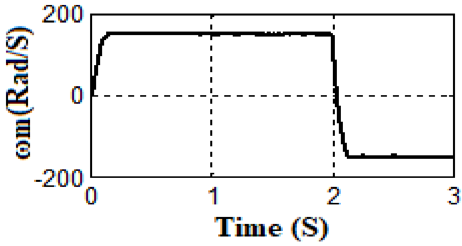

Fig. 6 Speed of SCIM.

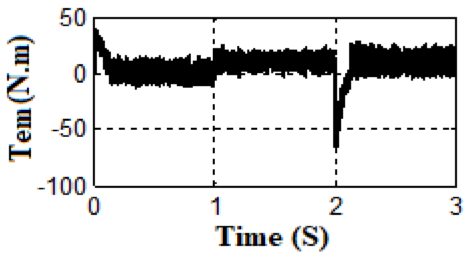

Fig. 7 Electromagnetic torque.

4. MULTIVARIABLE SLIDING MODE CONTROL WITH ROTOR FLUX OBSERVER

We have the following equations of state for the stator voltages:

$$\begin{cases} V_{Sd} = R_S.I_{Sd} + \sigma.L_S.\dfrac{dI_{Sd}}{dt} + \dfrac{M}{L_R}\dfrac{d\phi_{Rd}}{dt} - \\ -\omega_S \sigma L_S.I_{Sq} - \omega_S\dfrac{M}{L_R}.\phi_{Rq}. \\ V_{Sq} = R_S.I_{Sq} + \sigma.L_S.\dfrac{dI_{Sq}}{dt} + \\ +\dfrac{M}{L_R}\dfrac{d\phi_{Rq}}{dt} - \omega_S\sigma L_S.I_{Sd} - \omega_S\dfrac{M}{L_R}.\phi_{Rd}. \end{cases} \quad (22)$$

$$\begin{cases} V_S = \begin{bmatrix} V_{Sd} \\ V_{Sq} \end{bmatrix} = R_S.I.I_S + \sigma L_S.I.\dot{I}_S + \dfrac{M}{L_R}.I.\dot{\phi}_R + \\ +\omega_S.\sigma.L_S.J.I_S + \omega_S.\dfrac{M}{L_R}.J.\phi_R. \\ \hat{V}_S = \begin{bmatrix} V_{Sd} \\ V_{Sq} \end{bmatrix} = R_S.I.I_S + \sigma L_S.I.\dot{I}_S + \dfrac{M}{L_R}.I.\dot{\hat{\phi}}_R + \\ +\omega_S.\sigma.L_S.J.I_S + \omega_S.\dfrac{M}{L_R}.J.\hat{\phi}_R. \end{cases} \quad (23)$$

$$\begin{cases} \dfrac{d\hat{\phi}_{Rd}}{dt} = \dot{\hat{\phi}}_{Rd} = -\dfrac{\phi_{Rd}}{T_R} + \omega_g.\phi_{Rq} + \dfrac{M}{T_R}.I_{Sd}. \\ \dfrac{d\hat{\phi}_{Rq}}{dt} = \dot{\hat{\phi}}_{Rq} = -\dfrac{\phi_{Rq}}{T_R} + \omega_g.\phi_{Rd} + \dfrac{M}{T_R}.I_{Sq}. \end{cases} \quad (24)$$

Writing equations in matrix form:

$$\dot{\hat{\phi}} = \left[-\frac{I}{T_R} - \omega_g.J \right].\hat{\phi}_R + \frac{M}{T_R}.I.I_S + K.(\hat{V}_S - V_S) \quad (25)$$

With $K = k.I = \begin{bmatrix} k & 0 \\ 0 & k \end{bmatrix}$.

k : is the observer's gain.

Observer error: $e = \hat{\phi}_R - \phi_R$ (26)

The derivative of the error is:

$$\dot{e} = \dot{\hat{\phi}} - \dot{\phi} = \left[-\frac{I}{T_R} + J\left(\omega_g - K.\omega_S.\frac{M}{L_R}\right)\right].e + K.\frac{M}{L_R}.\dot{e}. \quad (27)$$

Let's put: $\omega_0 = \omega_g - K.\omega_S.\dfrac{M}{L_R}$ (28)

From where:

$$\dot{e} = \left(I - \frac{K.M}{L_R} \right)^{-1}.\left(-\frac{I}{T_R} - J.\omega_0 \right).e. \quad (29)$$

We now consider how to avoid having to bring derivatives into effect. First define the fallback variable:

$$z = [I - K.(M/L_R)].\hat{\phi}_R - K.(\sigma.L_S).I_S \quad (30)$$

$$\dot{z} = [I - K.(M/L_R)].\dot{\hat{\phi}} - K.(\sigma.L_S).\dot{I}_S \quad (31)$$

From the equation (31) we draw:

$$\sigma.L_S.\dot{I}_S = \hat{V}_S - (R_S.I + \omega_S.\sigma.L_S.J).I_S - \quad (32)$$
$$-\frac{M}{L_R}.I.\dot{\hat{\phi}}_R - \omega_S.\frac{M}{L_R}.J.\hat{\phi}_R$$

Using the equation (32) in the equation (31) we obtain:

$$\dot{z} = \dot{\hat{\phi}}_R + K.(R_S.I + \omega_S.\sigma.L_S.J).I_S + \quad (33)$$
$$+K.\omega_S.\frac{M}{L_R}.J.\hat{\phi}_R - K.\hat{V}_S.$$

Substitute $\dot{\hat{\phi}}_R$ by its value in the equation (33) we find:

$$\dot{z} = \dot{\hat{\phi}}_R + K.(R_S.I + \omega_S.\sigma.L_S.J).I_S + \quad (34)$$
$$+K.\omega_S.\frac{M}{L_R}.J.\hat{\phi}_R - K.\hat{V}_S.$$

Now show that:

$$\hat{\phi}_R = \left(I - K.\frac{M}{L_R} \right)^{-1}.(z + K.\sigma.L_S.I_S) \quad (35)$$

A. Diagram of a multivariable sliding mode control with rotor flux observer

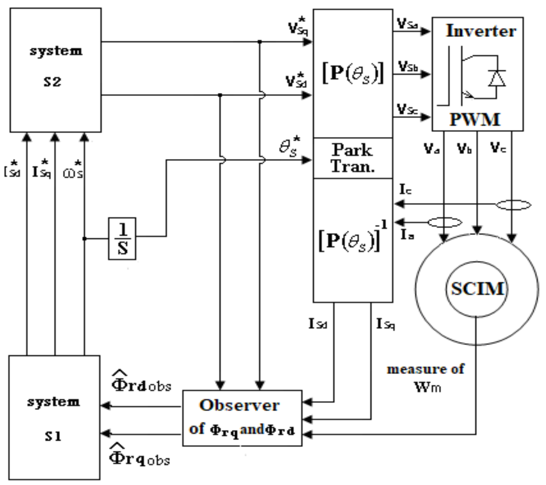

Fig. 8Multivariable sliding mode control diagrams of Squirrel Cage Induction Motor (SCIM) (Flux observer).

B. Simulation Results

For verifying the proposed rotor flux estimation of the SCIM, the simulations are carried out. SCIM is considered in the simulation and parameters as given in Appendix (Table 1).

The multivariable sliding mode controller (MSMC) algorithm is compared using the same rotor speed reference command.

The simulation results are shown in Figs 9-14 (stator currents direct and quadrature, rotor flux direct and quadrature, Speed of SCIM and Electromagnetic torque of SCIM.

The SCIM runs in speed regulation at 150 rpm between t =0 until t =2s, it undergoes a disturbance presented by the torque resisting at t =1s, the speed reference will change by 150 rpm a - 150 rpm. The current Isq perfectly follows its reference Isq* throughout the test. The current Φrd remains constant and equal to its reference value (Φr =1 Wb). The flux Φrq is simulated all the time, which proves the effectiveness of the control based on the rotor flux observer with the minimization and elimination of disturbances on the different electrical quantities.

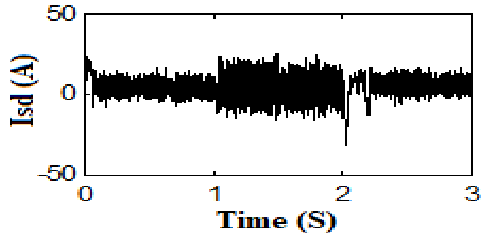

Fig. 9Stator current direct.

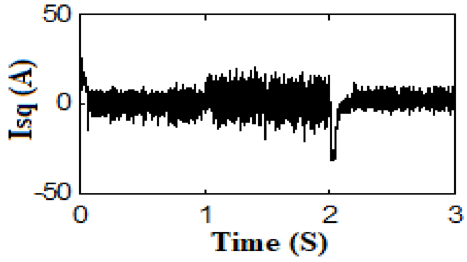

Fig. 10Stator current quadrature.

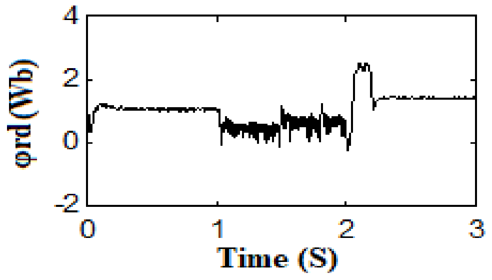

Fig. 11Rotor flux direct.

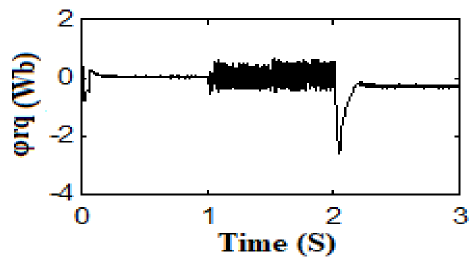

Fig. 12Rotor flux quadrature.

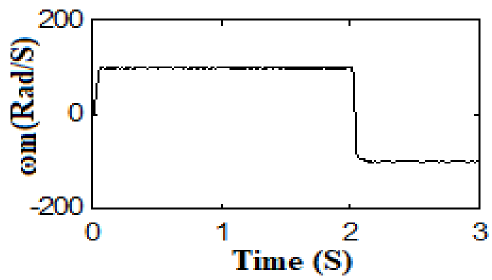

Fig. 13 Speed of SCIM.

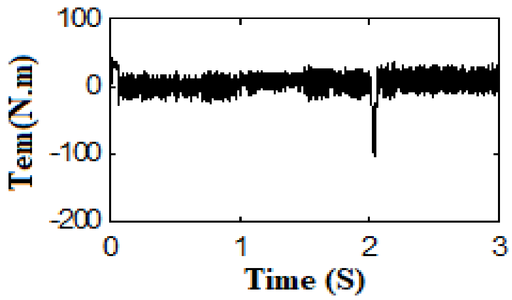

Fig. 14Electromagnetic torque.

5. CONCLUSION

This paper has proposed a multivariable sliding mode control (MSMC) for based estimation and observer method for the rotor flux of squirrel cage induction motor (SCIM). With the use of multivariable sliding mode control (MSMC), using a rotor flux estimator, more improved results were obtained than other methods of controls seen previously either at the disturbance level or at the set point tracking level, but with the implementation of an observer by sliding mode, thanks to which it is possible to collect information on the rotor flux, the simulation results have showed the effectiveness of such an observer, as well as its robustness properties by taking into account variations in mechanical speed.

6. APPENDIX

Table 1The parameters of the SCIM

Parameters	Values
Rated power	1.5 kW
Line voltage	230 V
Line current	3.64A/6.31A
Stator resistance Rs	4.85 Ω
Rotor resistance Rr	3.805 Ω
Stator inductance Ls	0.274 H
Rotor inductance Lr	0.274 H
Magnetising inductance M	0.258 H
Moment of inertia J	0.031 Kg.m2
Viscous friction coefficient f	0.008 N.s/rd
Number of pole pairs	2

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