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Speed sensorless control for DTC of induction motor using Luemberger observer

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***Abstract*— this paper presents a new strategy of induction motors drive using an extended Luemberger observer of speed sensorless direct torque control. Primary outcomes is to consolidate the DTC for induction machines, the drive is assisted by a Luemberger observer which simulation has shown a very good static and dynamic behaviour in speed control with a satisfied performance at low values. The robustness of simulation has shown that this observer replaces unknown parameters and variables; engine has given about the results satisfactory when the stability and robustness of the engine speed by renewing its reference value.**

***Keywords*— Control DTC, Induction Torque Control Sensorless, extended Luenberger observer (ELO).**

I. INTRODUCTION

Direct torque control (DTC) of induction motor drive offers high performance in terms of simplicity in control and fast electromagnetic torque response with dominant characteristics the direct torque controlled induction motor drive is one of the most alternative in industrial applications. The principle of the classical DTC is decoupled control of stator flux and electromagnetic torque using hysteresis control of stator flux error and torque error with stator flux position [1].The main advantages of sensors elimination in the sensorless induction motor (IM) drive is: lower costs, decrease of the driven motor dimensions, less cabling and increase of the system reliability. In recent years, remarkable efforts have been made to the development of state variables reconstruction of the induction motor, such as:

1°) Rotor or stator flux vectors, electromagnetic torque and rotor speed, to obtain sensorless drive systems these estimated methods are based on easily measurable

2°) Electrical signals – stator voltages and currents. One of the most popular solutions for speed reconstruction is based on the following schemes:

3°) Extended Luemberger observer (ELO)[3]. This method is more robust to parameters variation by introducing the error feedback of stator current estimation. [4].

II. . PRINCIPLE .

The main ideas are presented in the paper as the mathematical formulations and their derivative functions. This part should be followed by exact references

1 General principles of direct torque control

Using the vectorial expressions of the machine in the reference frame binds to the stator is defined by.

$$\begin{cases} \bar{V}s = Rs\bar{I}_s = \dfrac{d\bar{\psi}_s}{dt} \\ \bar{V}_r = 0 = Rr\bar{I}r + \dfrac{d\bar{\psi}_r}{dt} - j\omega\bar{\psi}_r \end{cases} \quad (1)$$

From the flux expressions above, the rotor current can be written

$$\bar{I}_r = \frac{1}{\sigma}\left(\frac{\bar{\psi}_r}{L_r} - \frac{L_m}{L_r L_s}\bar{\psi}_s\right) \quad (2)$$

With $\sigma = 1 - \frac{L_m^2}{L_s L_r}$ (variability (scatter) factor)

The equations become:

$$\begin{cases} \bar{V}_s = Rs\bar{I}s + \dfrac{d\bar{\psi}_s}{dt} \\ \dfrac{d\bar{\psi}_r}{dt} + \left(\dfrac{1}{\sigma\tau_r} - j\omega\right)\bar{\psi}_r = \dfrac{L_m}{L_s}\dfrac{1}{\sigma\tau_r}\bar{\psi}_s \end{cases} \quad (3)$$

These relations show that:

- We can possibly control the $\bar{\psi}_s$ vector starting from the $\bar{V}_s$ vector, with the voltage drop $R_s\bar{I}_s$
- The flux ψ_r follows the variation of ψ_s with time constant $\sigma\tau_r$. [5]

- The electromagnetic torque is proportional to the vectorial product of the stator and rotor flux vectors.

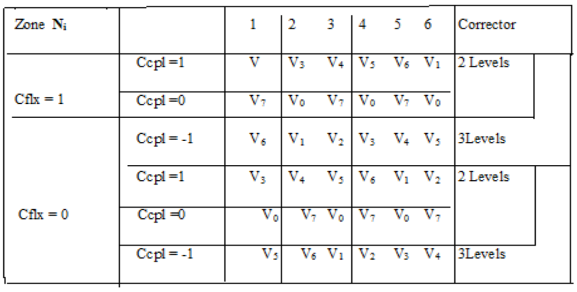
$$\Gamma_{elm} = p\frac{L_m}{\sigma L_s L_r}\psi_s\psi_r \sin\gamma \qquad (4)$$

With $\gamma = \left(\overline{\psi}_s \overline{\psi}_r\right)$

- Thus the torque depends on the amplitude and the relative position of the two vectors $\overline{\psi}_s$ and $\overline{\psi}_r$.

- If we perfectly manage to control the flux $\overline{\psi}_s$ (starting from $\overline{V}_s$) in module and position, we can thus control the amplitude and the relative position of $\overline{\psi}_s$ and $\overline{\psi}_r$, consequently the torque.

This can be possible only when the control period T_e of the voltage V_s is such as $T_e << \sigma\tau_r$ [6].



Zone N_i		1	2	3	4	5	6	Corrector
Cflx = 1	Ccpl =1	V	V_3	V_4	V_5	V_6	V_1	2 Levels
	Ccpl =0	V_7	V_0	V_7	V_0	V_7	V_0	
	Ccpl = -1	V_6	V_1	V_2	V_3	V_4	V_5	3Levels
Cflx = 0	Ccpl =1	V_3	V_4	V_5	V_6	V_1	V_2	2 Levels
	Ccpl =0	V_0	V_7	V_0	V_7	V_0	V_7	
	Ccpl = -1	V_5	V_6	V_1	V_2	V_3	V_4	3Levels

Fig.1 Trooth table of DTC structure

III. STATOR FLUX OBSERVER

Observer study allows the estimation of the rotor speed and the load torque with the stator current of induction motor.

The mathematical development of the adaptive observer is defined as [7], [8].

$$P\hat{I}_s = -\left[\left(\frac{1}{\sigma T_s} + \frac{1}{\sigma T_r}\right) - j\omega_r\right]\hat{I}_s + \frac{1}{\sigma l_s}\left(\frac{1}{T_r} - j\omega_r\right)\hat{\psi}_S + \frac{1}{\sigma l_s}u_s + G_1\left(I_s - \hat{I}_s\right) \qquad (5)$$

$$\mathrm{P}\widehat{\psi}_S = \mathrm{R_s}\hat{\mathrm{I}}_\mathrm{s} + \mathrm{G_2}\left(\mathrm{I_s} - \hat{\mathrm{I}}_\mathrm{s}\right) \qquad (6)$$

$$\frac{d\hat{\omega}_r}{dt} = \frac{N_p}{J}\left(\hat{C}_e - \hat{C}_L\right) + K_\omega\left[\Delta I_S \wedge (\lambda L_s)\hat{\psi}_s - \hat{I}_s\right] \qquad (7)$$

$$\frac{d\hat{C}_L}{dt} = -k_T\left[\Delta I_S \wedge (\lambda L_s)\hat{\psi}_s - \hat{I}_s\right] \qquad (8)$$

$$\lambda = \frac{L_r}{L_s L_r - M^2} = \sigma l_s \qquad (9)$$

Where $\hat{I}_s$ *and* $\hat{\psi}_S$ are current and estimated stator flux respectively

$G_1 = -(g_{1r} - jg_{1i})$ *et* $G_2 = -(g_{2r} - jg_{2i})$ are the gains of the observer

Observer gain selection

Kw et Kt are positive constant gains.

$$g_{1r} = 2b \qquad (10)$$

$$g_{1i} = 0 \qquad (11)$$

$$g_{2r} = \frac{b}{\lambda l_r} \qquad (12)$$

$$g_{2i} = 0 \qquad (13)$$

Where b is a constant negative gain, to validate the effectiveness of the proposed technique, a system is simulated and the results are presented below. Figure (2).

IV. DRIVE SYSTEM

The system is basically constituted of the order of DTC MAS which has static and dynamic performance and a remarkable robustness. Never the less the DTC for a drive at low speeds due to a substantial increase in its resistance disrupts its training [9]. We use the observer Luemberger to renew the drive speed reference value whatever the foresight that affects our gain [10].

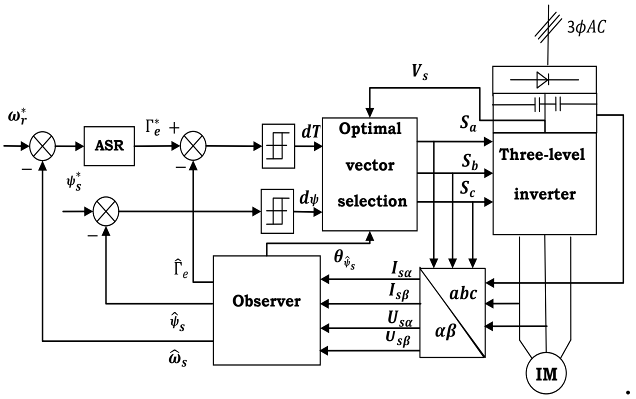


Fig.2 Bloc diagram of Sensorless three-levels DTC drive with Observer stator flux

TABLE I
MACHINE'S PARAMETERS

DC-bus voltage[V]	V_{dc}	440
Rated motor power[kW]	P_N	4
Rated motor voltage [V]	U_N	220
Rated motor frequency[Hz]	f_N	50
Number of motor pairs	N_p	2
Motor stator resistance [Ω]	R_s	1.2
Motor rotor resistance [Ω]	R_r	1.8
Motor stator inductance [H]	L_s	0.1564
Motor rotor inductance [H]	L_r	0.1564
Motor mutual inductance [H]	L_m	0.15

V. SIMULATION RESULTS TEST OF ROBUSTNESS

a) Load starting

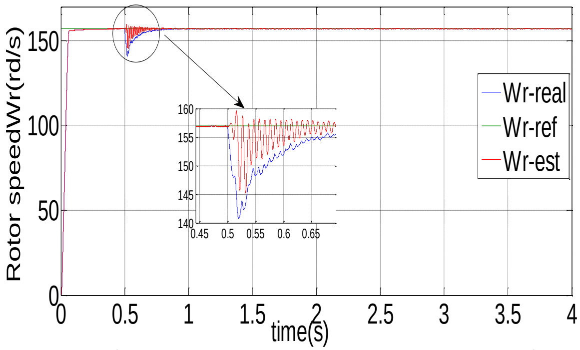


Fig. 3 Evolution of estimated and actual speeds, in the presence of the observe

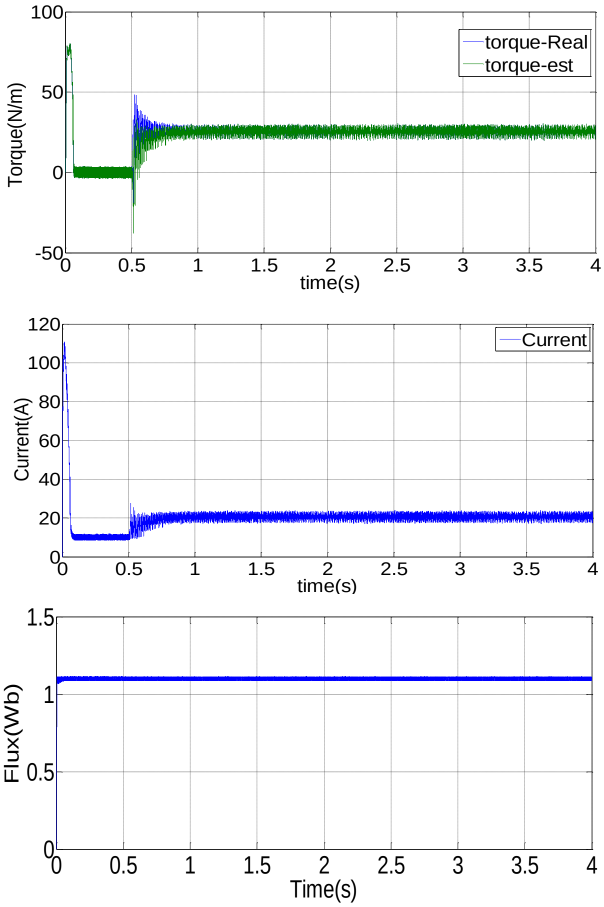


Fig.4 The estimated evolution of torque and actual Max current and stator flux observer in the presence of observer

We note that the estimated speed and the real one, which are of the order of 157rd / s present a satisfactory response time. However, the module follows the reference stator flux of 1.1 Web and the applied torque to the machine shows less ripples than the real one and follows the imposed consign which is nil for convenience, whereas the stator flux module follows its given reference of 1.1 Web.

b) Start low speed 157rd / s 20rd / s

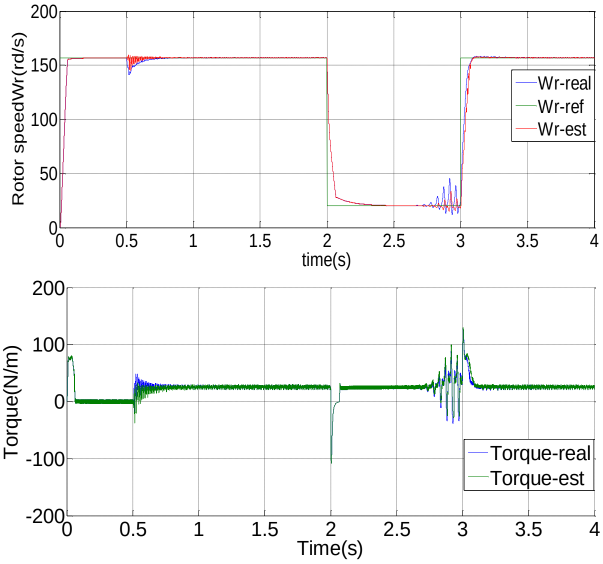


Fig.5 Real estimated speed and torque evolution of MAS using Luenberger observer

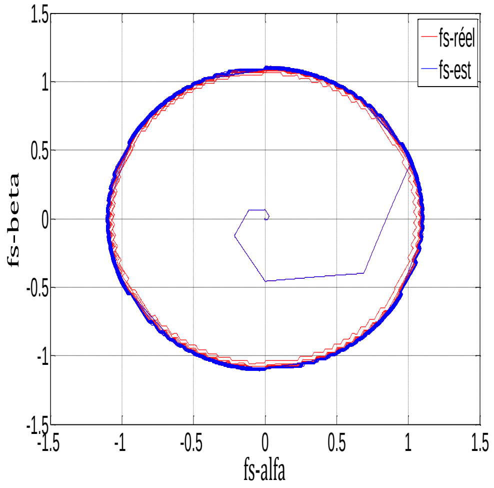


Fig.6 Evolution of the trajectory and the actual stator flux estimated by the Luenberger observer

When operating at reduced speed the observer follows a remarkable way and even with significant reduction of torque ripples and stator flux, when changing flux path according to Park transformation responds perfectly.

V. CONCLUSIONS

We have introduced in this article the speed sensorless control for DTC of induction motor using Luemberger observer control approach. The choice of this method for the control of asynchronous machines is justified. Having chosen the Matlab/Simulink as tools of simulation under several operating conditions to observe a good static and dynamic speed. Satisfactory performance at low speed, a good disturbance rejection with an acceptable reduction of the torque ripples. The stator flux is estimated and indeed imposed following the given references.

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