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Diagnosis and Order Without Sensors Asynchronous Machine Usage by the Application Techniques of Estimate

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Abstract: This study presents the application of estimate techniques, in particular observer technique, in the diagnosis and the order without induction sensor engine. The engine with induction has the advantage of being robust, inexpensive and of simple construction. For these reasons it remains very appreciated and reliable for applications to high dynamic performances in the industrial world. The development of estimate techniques and microcontrôleurs appearance, DSP at low cost, for the data processing make engine with induction an exceptional actiner thanks to an excellent mass couple, a maximum reliability and a significant transitory surcouple. To preserve the correct operation of these systems, it is essential to supervise their operating condition in a continuous way. As a metter of fact the monitoring requires in its turn a set of apparatuses or measuring instruments, that are not alaways available, to provide data relating to the various operating modes from the system. Although the objective of this study is to reduce the number of measuring apparatus, for technological or economic reasons and consequently, sensors and wiring. This material is to be replaced by software built on the basis of estimator of states reducing in this way the cost of the installations and thus increases their reliability and automatically the output of production.

Key words: Sensors, eltimate techniques, diagnosis

INTRODUCTION

With the appearance of modern variators especially the variators with vectorial order and the microcontrôleurs thanks to an excellent mass couple, a maximum reliability, surcouple transitory significant. Thus importance and necessity study of the modeling of the asynchronous machines for order, primarily the order without sensors. The importance of this order is that makes it possible to increase the robustness and the reliability of the machine and consequently reduce drive systems cost and order containing asynchronous machine. The asynchronous machines advantage is of being robust, cheaper, de simple construction and it requires only little maintenance. For these reasons the machine with induction remains always very appreciated in the industrial world and thus for applications that require high dynamic performances concerning.

Various works estimate in real time of sizes and parameters were already completed. The modern techniques, in particular the observers of Luenberger and of Kalman requires a model of state of the asynchronous machine. This is the objectives of our study this study general model of the asynchronous machine is presented in the space of state per report/ ratio to an arbitrary reference frame and having for variable of state the stator current and rotor flow. Thanks to the technique of orientation of rotor flow this model can model could be reduced and small-scale model are presented in this study. The linear and nonlinear alternatives of this model as well as the possibility of estimate of rotor resistance in the study of the model are aiso discussed in this study from a theoretical sight.

Asynchronous machine modeling: The engine with induction is a nonlinear and nonstationry system. Its model complexity of its could be simplified by using the PARK transformation are mentioned and the orientation of flow technique. Various models exist the literature.Thus be able apply the modern techniques of order and systems monitoring, the representation by model of state is the most suitable.

The model of the engine with induction in the space of state and in an arbitrary reference mark (initial) is given by.

$$\frac{d}{dt}\Psi = \Omega\,\Psi - RI + I_0 U \qquad (1)$$

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$$\Psi = L_M I \quad (2)$$

With : $\Psi = \begin{bmatrix} \varphi_s \\ \varphi_r \end{bmatrix}$ is the vector of flow,I $= \begin{bmatrix} i_s \\ i_r \end{bmatrix}$ is the vector current,

$U = \begin{bmatrix} u_s \\ u_r \end{bmatrix}$ is the vector of voltage.

The matrix Ω, R, I_0 and M are defined by:

$\Omega = \begin{bmatrix} \Omega_a & 0_2 \\ 0_2 & \Omega_{ar} \end{bmatrix}$ with: $\Omega_a = \begin{bmatrix} 0 & \omega_a \\ -\omega_a & 0 \end{bmatrix}$, $\Omega_{ar} = \begin{bmatrix} 0 & (\omega_a - \omega_r) \\ -(\omega_a - \omega_r) & 0 \end{bmatrix}$, $R = \begin{bmatrix} R_s & 0_2 \\ 0_2 & R_r \end{bmatrix}$,

With: $R_s = \begin{bmatrix} r_s & 0_2 \\ 0_2 & r_s \end{bmatrix}$, $R_r = \begin{bmatrix} r_r & 0_2 \\ 0_2 & r_r \end{bmatrix}$, $L_M = \begin{bmatrix} L_s & M \\ M & L_r \end{bmatrix}$,
With, $L_s = , \begin{bmatrix} l_s & 0_2 \\ 0_2 & l_s \end{bmatrix}$

$L_r = \begin{bmatrix} l_r & 0_2 \\ 0_2 & l_r \end{bmatrix}$, $M = \begin{bmatrix} m & 0_2 \\ 0_2 & m \end{bmatrix}$ and in end $I = \begin{bmatrix} I_2 & 0_2 \\ 0_2 & 0_2 \end{bmatrix}$.

The matrix inversion lemma of is used to simplify calculations and facilitate the transformation of the various asynchronous machine dynamic models of the according to choice's of the variables of state. Matrix L_M given by:

$L_M = \begin{bmatrix} L_s & M \\ M & L_r \end{bmatrix}$ has as a reverse: L^{-1}_M

$$= \begin{bmatrix} (L_s - ML_r^{-1}M^T)^{-1} & -(L_{sr} - M L_r^{-1} M^T)^{-1} M L_R^{-1} \\ -(L_r - M^T L_s^{-1} M)^{-1} M^T L_s^{-1} & (L_r - M^T L_s^{-1} M)^{-1} \end{bmatrix} \quad (3)$$

Various models corresponding to different reference marks and various states variables choices are possible. Among these models we notice the study of the stator current and rotor flow as variables of state. The models is written then:

$$\frac{d}{dt}\begin{pmatrix} i_s \\ \varphi_s \end{pmatrix} = \begin{bmatrix} a_{11} & a_{12} \\ -R_s & \Omega_a \end{bmatrix} \begin{pmatrix} i_s \\ \varphi_s \end{pmatrix} + \begin{bmatrix} b_{11} \\ I_2 \end{bmatrix} u_s$$

The expression speed is given by this relation:

$$\frac{d\omega_r}{dt} = \frac{1}{J}\frac{p}{2}(T_e - T_l) \quad (4)$$

Electromagétic torque is presented by:

$$T_e = p i_s^T \begin{bmatrix} 0 & -1 \\ 1 & 0 \end{bmatrix} \varphi_s \quad (5)$$

The evolution matrix parameters are:

$$a_{11} = \Omega_{ar} + (M - L_r M^{-1} L_s)^{-1} (R_r M^{-1} L_s + L_r M^{-1} R_s)$$
$$a_{12} = (M - L_r M^{-1} L_s)^{-1} \left[(\Omega_a L_r - R_r) M^{-1} - L_r M^{-1} \Omega_a \right]$$
$$a_{21} = -R_s, \qquad a_{22} = \Omega_a,$$
$$\text{and } b_{11} = -(M - L_r M^{-1} L_s)^{-1} L_r M^{-1}$$

This model is linear, nonlinear model case could be obtained by regarding the number of revolutions as an additional state variable. In this last case the algorithms of order or monitoring are complicated[1].

Technique of state estimate: Suppose a continous system described by the following state deterministic Eq:

$$\dot{x}(t) = Ax(t) + Bu(t), \quad (6)$$

$$\dot{y}(t) = Cx(t) + Du(t), \quad (7)$$

Where U(t), y(t) and X(t) are dimension vectors m, l and n and consecutively represent the order, the measured exit and the system state. The matrix A, B, C and D are constant matrix of suitable dimensions[2]. As the state is not generally accessible, the objective of an observer consists in estimating this state by a variable which we will note $\hat{x}(t)$. This estimate is carried out by a dynamic system that output exit will be precisely $\hat{x}(t)$ and the input will be consisted of the whole of information available, i.e. U (t) and y (t).

The structure of an observer has the form:

$$\hat{x}(t) = A\hat{x}(t) + Bu(t) + L(y(t) - \hat{y}(t)), \quad (8)$$

$$\hat{y}(t) = C\hat{x}(t) + Du(t), \quad (9)$$

Corrective term according to the error of output rebuilding appears clearly here y(t)-ŷ(t) and the profit of correction, L, called profit of the observer. It is to be determined.

This structure could be also written in the following equivalent form:

$$\dot{\hat{x}}(t) = (A - LC)\hat{x}(t) + (B - LD)u(t) + Ly(t) \quad (10)$$

if we consider estimation error: $\tilde{x}(t) = x(t) - \hat{x}(t)$ one oblains then

$$\dot{\tilde{x}}(t) = (A - LC)\tilde{x}(t), \quad (11)$$

In this study, a great freedom is left to the choice of the eigenvalues, but in practice we choose an error dynamics faster than that of process in study of an observation in open loop or than that desired in closed loop.

However we could not consider them infinitely for two essential reasons we can use only realizable profits and the increase in the band-width of the reconstructor does not make it possible any more to neglect noises becoming dominating in high frequency.

The physical complexity of the electric machines such as the asynchronous machine is related to electromagnetic interactions between stator and rotor. The state sizes oroutput used for order development or the monotoring of motorized systems are often difficult to reach for technical reasons or problems of cost.

They thus, should be determined without using sensors dedicated starting from the already measured sizes (current, voltage,...).

They can being reconstituted by traditional estimators used in open loop or modern estimators correcting in closed loop the estimated variables. The estimator techniquelies on the usage of a machine representation in the from of equations of state defined in the reference mark of Park. In steady operation (static estmator) or transient (dynamic estimator), they are obtained by direct resolutions of equation associated with this model.

For using a system in a chain of order it is first of all necessiry to study the possibilities of measurment which could be taken on the real system and the possibilities of ordering it. The possibilities of measurement on the real system constitute the observability conditions of the system and the possibiities of ordering it constitute, the conditions of commandability. These two concept use also the représentation of state, in other words the model of the asynchronous machine.

Application of the observers of state to the monitoring: In addition to the state rebuilding to study out an order by return of state, we will see here another significant application of the observers in order, detection and diagnosis of the failures[3], in the electric machines. In these optics we use the observer to generate residues

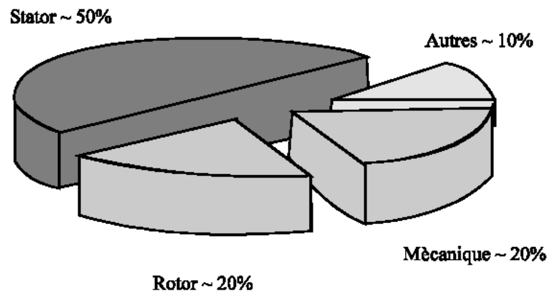

Fig. 1: The distribution of the beakdowns

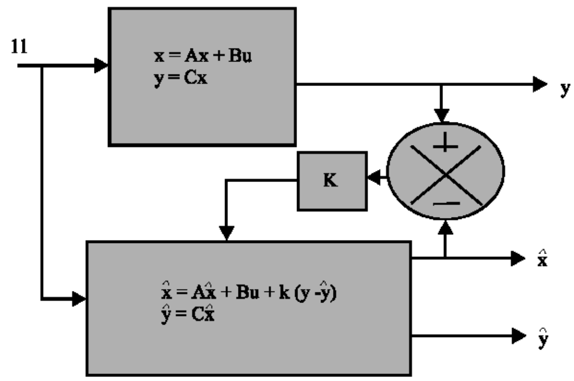

Fig. 2: Principale of an observer of state

allowing to study out a decision in a stage of monitoring of the system during the appearance of the disturbances or the defects[4]. Indeed, the varaibles which act on the system cannot be measured and the objective of the observer consists in building residues which, according to case's, must be sensitive to the defects and insensitive with the disturbances.

In all the methods of detection of the failures suggested in the literature[5,6], one must take one or more signals to treat them or not, analyze them and show a failure, with certainty. For the stator, the effects of the failures are mainly due to a thermal problem (overload), electric (dielectric), mechanics (winding) or environmental (aggression). For the stator, the effects of the failures are mainly due to a thermal problem (overload), electric (dielectric), mechanics (winding) or environmental (aggression).

With this intention, four elementary signals could be taken It is about the stator current, of the radiating flow of the machine, the vibrations, number of revolutions. But in our study it is a diagnosis without sensors or more exactly a diagnosis with a minimum of sensors. The order and monitoring principle without sensors is given by Fig. 2.

Digital simulation: To highlight the performances of the technique of monotoring suggested we consider an engine with induction having the folowing characteristics:

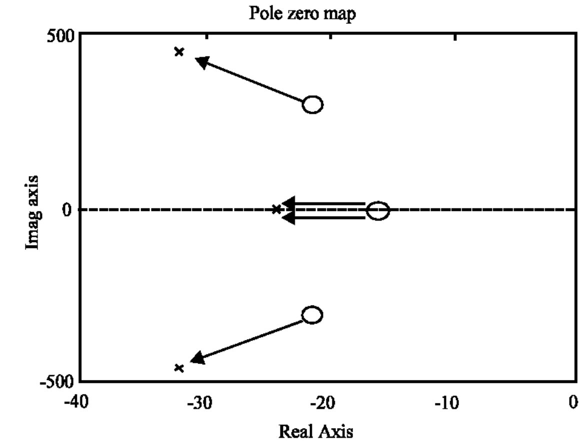

Fig. 3: Rebuiling of the system

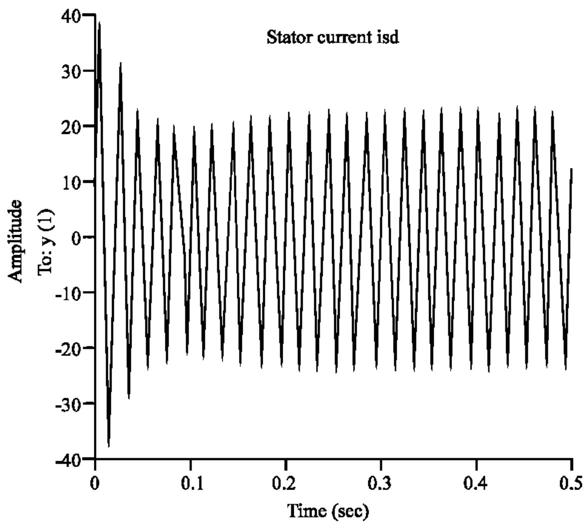

Fig. 4 : Etimeted stator current

f_r =50Hz, U = 220V, ω_m = 146.6rd/s, r_s = 0.63Ω, r_r = 0.4Ω, l_s = 0.097H, l_r = 0.091H ,

$$m = 0.091\,H,\ \sigma = 1 - \frac{m^2}{l_s l_r} = 0.0682,\ T_r = 0.2275,$$

T_s =.0.1539, f = 1Ns/rd, J = 0.22kgm^2.

Simulation consists of the study of the dynamic properties of the asynchronous machine in the space of state by using by using softhout MATLAB to see the possibilities of detection without sensor. The Fig. 3 presented the position of the poles of the observer compared to the poles of the system which show that the dynamics of the observer gives an answer faster than the dynamics of the machine.

Figure 4 and 5 are the stator current and rotor flow estimated respectively, and Fig. 6 shows the estimated electromagnetic torque.

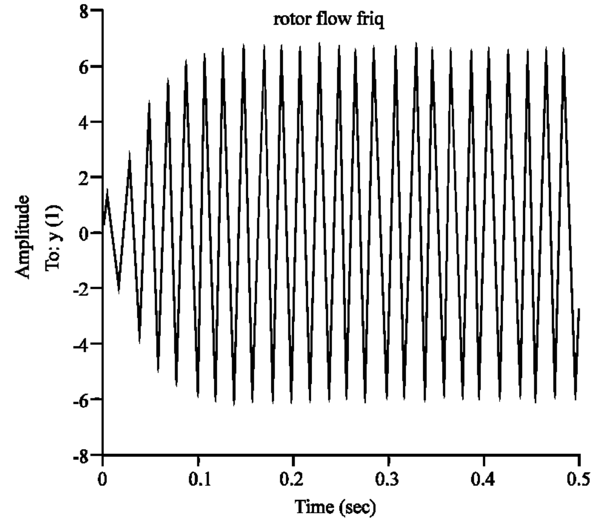

Fig. 5: Estimeted rotor field

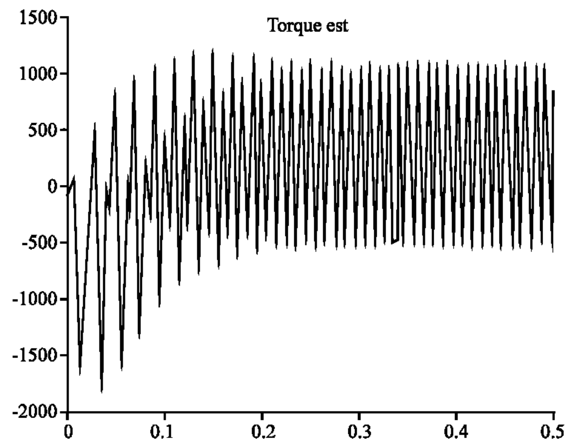

Fig. 6 : Estimeted torque

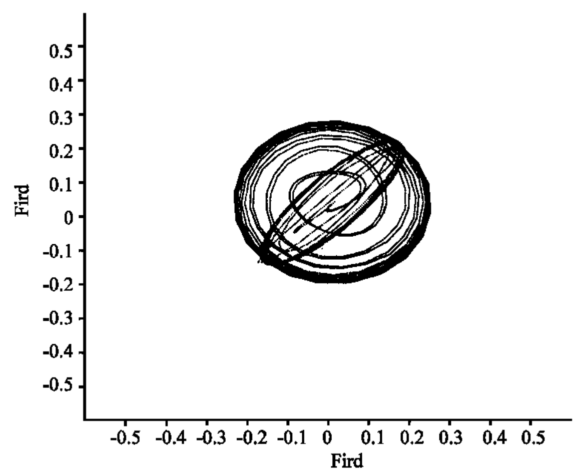

Fig. 7: Curve of lissajou in complete mode

It is enough to make recordings of the variables of state estimated of the operational engine (on the figure

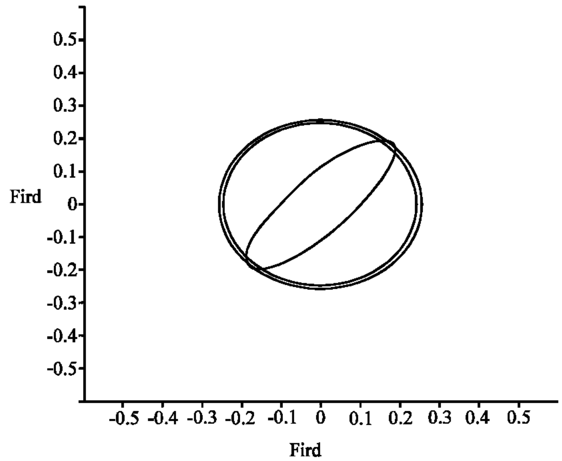

Fig. 8: Curve of lissajou in steady operation

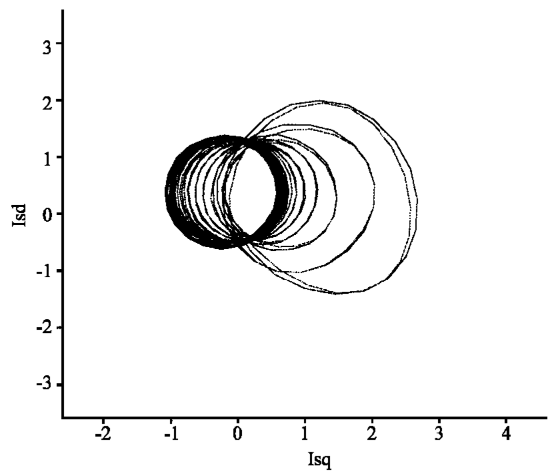

Fig. 9: Curve of lissajou in complete mode (+5% Rr)

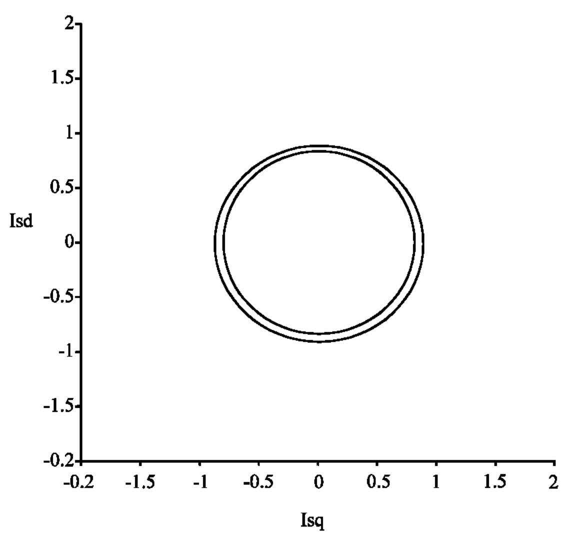

Fig. 10: Curve of lissajou in steady operation (+ 5% Rr)

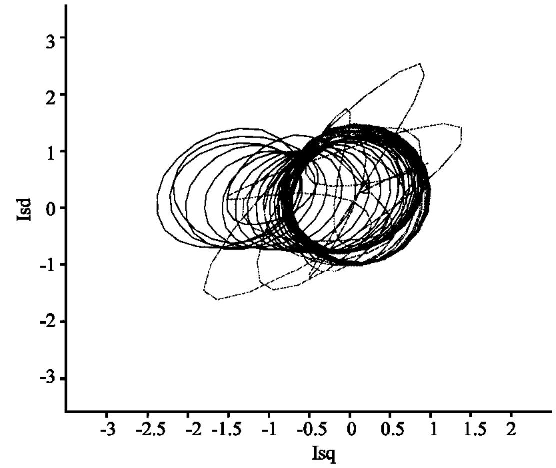

Fig. 11: Curve of lissajou in complete mode (- 5% Rr)

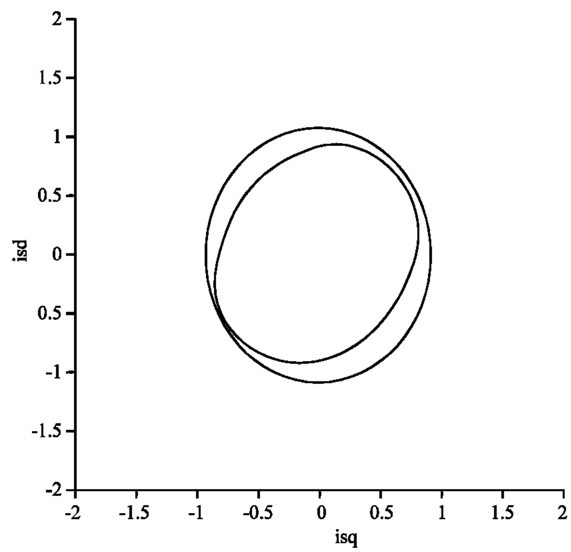

Fig. 12: Curve of lissajou in steady operation (- 5% Rr)

the healthy state is represented in blak and the failing recording is in red (variation of the stator resistance of 5%) and blue (varaition of the rotor resistance of 5%)) and to make a comparaison with the results estimated in the event of failure by using the analysis of the curves or the spectral analysis[1].

These results represents only the results obtained by the analysis of the current, estimated flow and also the possiblity of analyzing other variables as the electromagnetic torque.

Figure 7 the signature of dephasing on the curve of lissajou in complete mode, the healthy state in blue and the recording weakening and red and black. This signature which enables us to easily determine nature of defect and well on touts results obtained and estimated to ensure a diagnosis without sensors or at least of sensors. The Fig. 8 shows the signature of dephasing on the curve of lissajou in steady operation which also makes it possible to determine the nature of defect easily.

One little also to detect the rotor defects such as the break of the bars of the cage, Fig. 9 shows on the curve of lissajou the signature of this break in complete mode with increase de+5% of rotor resistance (reduction in the intensity) here uses of it the current estimated same manner Fig. 10 shows on the curve of lissajou of this break but in steady operation.

Also, the defects stator can be detected by the same technique, here one has one on intensity. Figure 11 shows the signature on the curve of lissajou in complete mode with a reduction of –5% of stator resistance. Of the same way Fig. 12 shows this signature in steady operation with the same value of stator resistance.

In little also to make a spectral analysis after transformation of fourrier of each vector of state, which gives the spectrum in the healthy and failing case.

REFERENCES

1. Bensaker, B., H. Kherfane, A. Metatla and R. Wamkeue, 2003. State Space Modelling of inductions Motors for Sensorless Control and Monitoring Purposes. 5th Inter Symp ou Advaunced electromechanical motion systems, Marakech, pp: 483-488.
2. Bensaker, B., 1999. Parameter Estimation for an Electromechanical System via a Continuous-Time Model. Proceedings of the 3-rd International Symposium on Advanced Electromechanical Motion Systems, University of patras, Greece, pp: 759-762.
3. Holtz, J., 2002. Sensorless control of Induction Motor Drives. Proceedings of the IEEE, n°8, pp: 1359-1394.
4. Roboam, X., 1993. Variateur de vitesse pour la machine asynchrone, controle de vitesse sans capteur mécanique. Thèse de doctorat de l'INPT., Toulouse, France.
5. Luenberger, D.G., 1971. An introduction to observer, IEEE trans. Automatic. Control, AC- 16, pp: 596-603.
6. DU, T. and A. Brdys, 1993. Implementation of extended Luenberger observer for joint state and parameter estimation of PWM induction motor drive, EPE Proceedings, EPE Brighton, Brighton, England, pp: 439-444.