Vectorial Control of Asynchronous Machine Presenting the Defective Bars Rotor

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Abstract- With progress of the electric genius, the asynchronous motors replace more and more the engines with requiring D.C. current in the applications variable speed.
The machine is controlled from variable speed with the constraints of operation that that supposes. In this article, we present modeling as well as the vectorial control of the machine when a defect occurs in the machine. We will then see the effect of the rupture of the bars on the instructions of control.

Key words: Asynchronous motor, Modeling, vectorial Order, Detection, Rupture of bar.

I. INTODUCTION

The asynchronous machine, whose only electric entry is on the stator, poses problems for its control.

The scalar control is the oldest method used for the asynchronous machine control. The simplicity of implementation of this method makes it prefer in systems not requiring operations at very low speed and strong torque. In the contrary case, it is necessary to call upon the vectorial method to obtain high performances and to improve the dynamic behavior of the machine [1] [2].

II. MODELING OF THE ASYNCHRONOUS MACHINE

The study of the electric machines and their control in dynamic mode requires the use of a particular method of modeling. Currently the most used is that of Park.

the flows in the reference frame of Park are given by the relations:

$$\begin{cases}\Phi_{ds} = L_{sc}.I_{ds} + M.I_{dr}\\ \Phi_{qr} = L_{sc}.I_{qs} + M.I_{qr}\\ \Phi_{dr} = M.I_{ds} + L_{rc}.I_{dr}\\ \Phi_{qr} = M.I_{qs} + L_{rc}.I_{qr}\end{cases}$$

By taking account of these relations, the mechanical power *Pm* can be written:

$$P_m = \frac{3}{2}\left(\Phi_{ds}.I_{qs} - \Phi_{qs}.I_{ds}\right)\frac{d}{dt}\left(\theta_s - \theta_r\right)$$

$$\text{avec :}$$

$$\frac{d}{dt}\left(\theta_s - \theta_r\right) = \frac{d\theta}{dt} = \text{P}.\Omega$$

The electromagnetic torque is given by:

$$C_e = \frac{3}{2}\text{P}\left(\Phi_{ds}.I_{qs} - \Phi_{qs}.I_{ds}\right)$$

The equations of the tensions of the machine are written in the reference frame related to the spinning field pattern as follows:

$$\begin{cases}V_{ds} = R_s.I_{ds} + \dfrac{d\Phi_{ds}}{dt} - \omega_s.\Phi_{qs}\\ V_{qs} = R_s.I_{qs} + \dfrac{d\Phi_{qs}}{dt} + \omega_s.\Phi_{ds}\\ 0 = R_r.I_{dr} + \dfrac{d\Phi_{dr}}{dt} - \omega_r.\Phi_{qr}\\ 0 = R_r.I_{qs} + \dfrac{d\Phi_{qr}}{dt} + \omega_r.\Phi_{dr}\end{cases} \qquad (1)$$

III. VECTORIAL CONTROL OF THE MACHINE

The goal of the vectorial control is to manage to control the asynchronous machine like a D.C machine with separated excitation, where there is a natural decoupling between the size ordering flow (the operate current) and torque it (the armature current). This decoupling makes it possible to obtain a very fast response of the torque.

The mark of reference (d q) is related to rotor flow so that the rotor vector flow is according to axis d. the two components of stator current Ids and Iqs will be the variables of entry of an decoupling control of flow and couple:

Now we have:

$$\begin{cases}\Phi_{dr} = \Phi = \text{cste}\\ \Phi_{qr} = 0\end{cases}$$

A. Equations of the tensions

The equations of the machine in a reference related to the spinning field pattern become [1] [5]:

$$\begin{cases} V_{ds} = R_s.I_{ds} + \sigma.L_{sc}\dfrac{dI_{ds}}{dt} + \dfrac{M}{L_{rc}}\dfrac{d\Phi_r}{dt} - \omega_s\sigma.L_{sc}.I_{qs} \\ V_{qs} = R_s.I_{qs} + \sigma.L_{sc}\dfrac{dI_{qs}}{dt} + \omega_s\dfrac{M}{L_{sc}}\Phi_r + \omega_s\sigma.L_{sc}.I_{ds} \\ \Phi_r = \dfrac{M}{1+\mathrm{P}.\tau_r}.I_{ds} \\ \omega_r = \dfrac{M}{\tau_r.\Phi_r}.I_{qs} \end{cases} \tag{5}$$

Ainsi : $\Phi_r = M.I_{ds}$

$$\begin{cases} V_{ds} = R_s.I_{ds} + \sigma.L_{sc}\dfrac{dI_{ds}}{dt} + \dfrac{M}{L_{rc}}\dfrac{d\Phi_r}{dt} - \omega_s\sigma.L_{sc}.I_{qs} \\ V_{qs} = R_s.I_{qs} + \sigma.L_{sc}\dfrac{dI_{qs}}{dt} + \omega_s\dfrac{M}{L_{sc}}\Phi_r + \omega_s\sigma.L_{sc}.I_{ds} \\ \Phi_r = \dfrac{M}{1+\mathrm{P}.\tau_r}.I_{ds} \\ \omega_r = \dfrac{M}{\tau_r.\Phi_r}.I_{qs} \end{cases}$$

Ainsi : $\Phi_r = M.I_{ds}$

$$\begin{aligned} V_{ds} &= (R_s + \sigma.\mathrm{P}.L_{sc}).I_{ds} - \sigma.L_{sc}.\omega_s.I_{qs} \\ V_{qs} &= (R_s + \sigma.\mathrm{P}.L_{sc}).I_{qs} + \sigma.L_{sc}.\omega_s.I_{ds} + \frac{M}{L_{rc}}.\omega_s.\Phi_r \end{aligned} \tag{6}$$

$$V_{dr} = 0 = R_r \cdot I_{dr} + \frac{d\Phi_{dr}}{dt} - w_r\Phi_{qr}$$

Alors :

$R_r \cdot I_{dr} = 0 \Rightarrow I_{dr} = 0$ puisque $R_r \neq 0$

from Equation (1), we deduce:

$$\Phi_{qr} = M.I_{qs} + L_{rc}.I_{qr} = 0$$

$$\text{d'où : } I_{qr} = \frac{-M}{L_{rc}}.I_{qs}$$

What leads to the expression:

$$C_e = \frac{3}{2}\mathrm{P}.\frac{M}{L_{rc}}.\Phi_r.I_{qs}$$

There are methods of direct and indirect vectorial control. In this one, the angle of Park θs is calculated starting from the stator pulsation. For the direct control, the angle of Park is calculated directly using the measured or estimated sizes.

B. IIndirect vectrial control by oriented rotor flow

In this type of control, the angle θs uses for the transformation direct and opposite is calculated starting from the following formula [3] [4].

Where: $I_{ds} = \dfrac{\Phi_r}{M}$

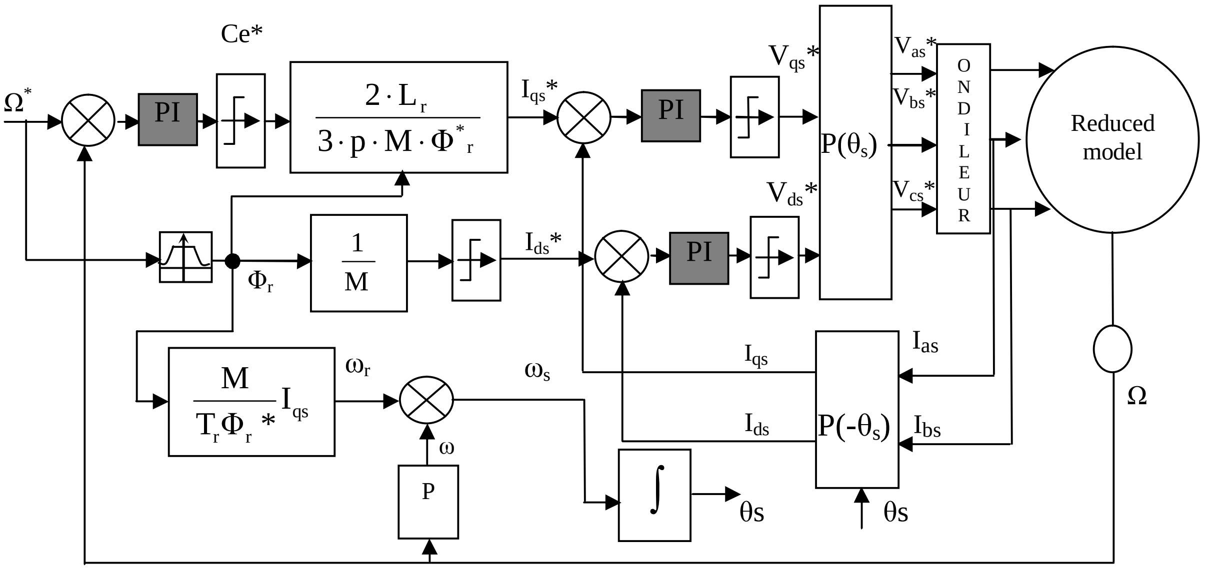


Figure 1 : Speed Regulation by the indirect vectorial control

with :

$$\begin{cases} e_d = -\sigma.L_{sc}.\omega_s.I_{qs} \\ e_q = \sigma.L_{sc}.\omega_s.I_{ds} + \dfrac{M}{L_{rc}}.\omega_s.\Phi_r \end{cases} \tag{7}$$

e_d, e_q : the f.e.m. of decoupling

VI. APPLICATION OF THE VECTORIAL CONTROL OF THE MACHINE PRESENTING THE BROKEN BARS

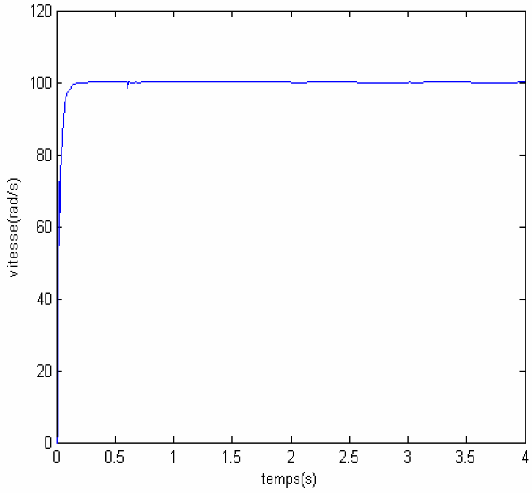
We present a simulation of the operation of an asynchronous motor with power of 1.1kW at the state of failing.

We present the influence of the rupture of bar on the operating of the asynchronous machine in vectorial control.

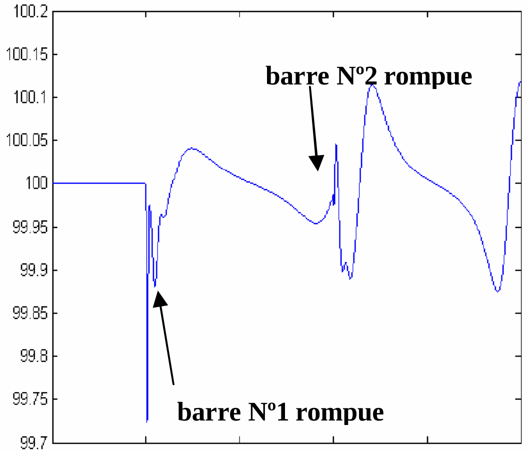
A. Indirect control without inverter

The simulation is carried out in duration of 4 sec in the manner below.

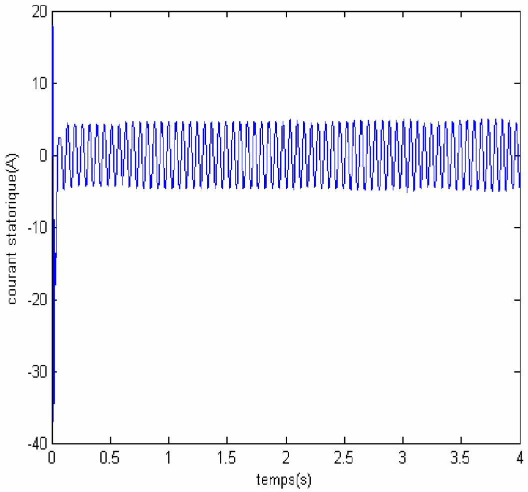
We start the machine without load. On t=0.6s a load of 3.5N.m is applied. At the moment t=2s a first bar is broken. Bar 2 is broken at the moment t=3s.



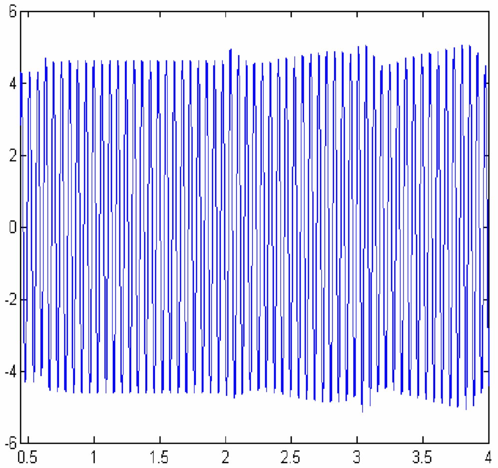
a. Rotation Speed



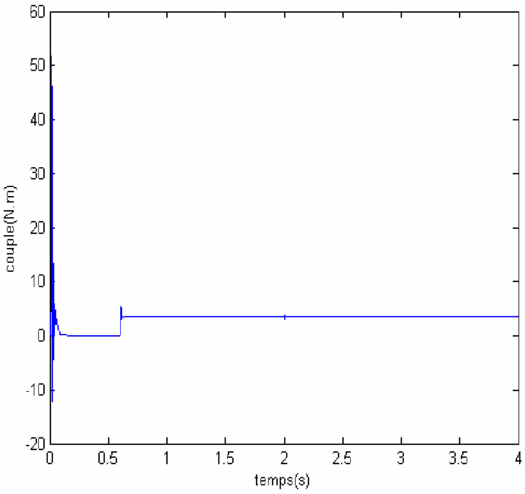
Enlarging of speed



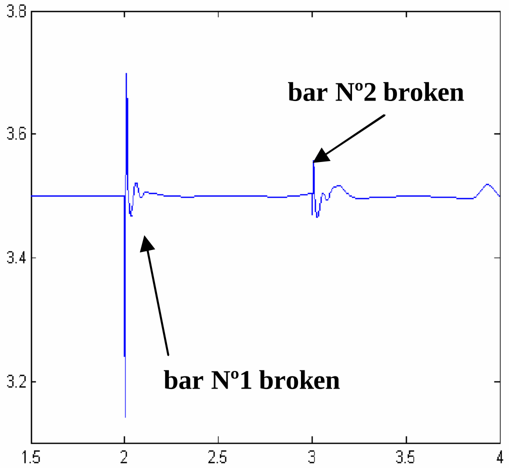
b. Stator Current



Enlarging of current



c. Electromagnetic Torque



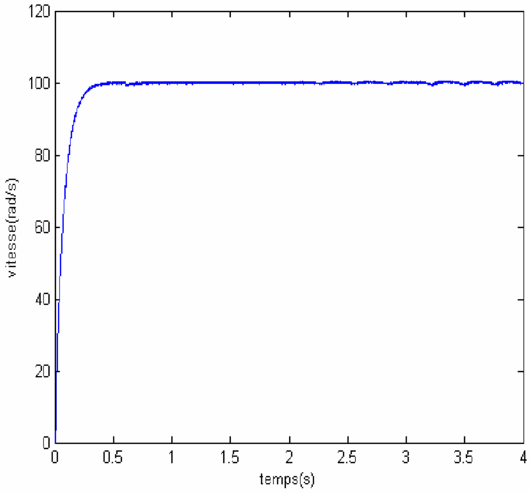
Enlarging of torque

Figure.2. Simulation with the reduced model: machine loaded (Cr=3.5N.m) with successive ruptures bars 1 after 2 starting from t=2s

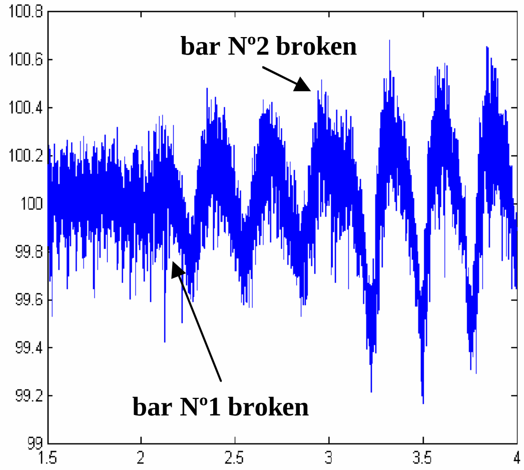
B; Indirect control with inverter

The simulation is carried out over one duration of 4s in the manner below.

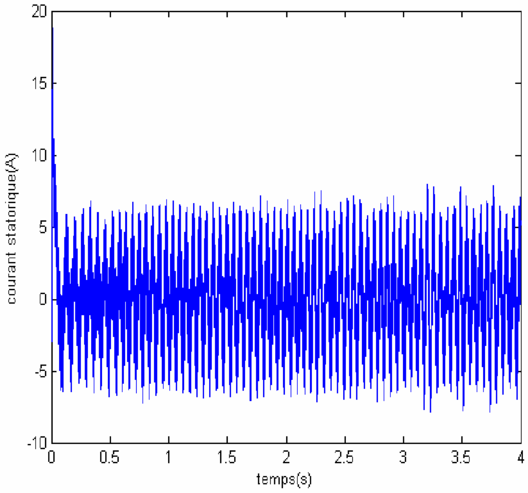
We start the machine without load. at t=0.6s a load of 3.5N.m is applied. At the moment t=2s a first bar is broken. Bar 2 is broken at the moment t=3s.



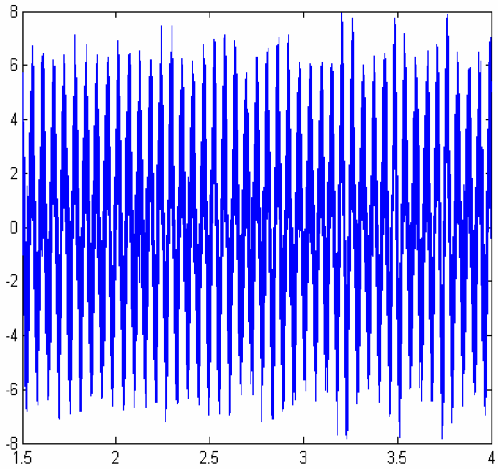
a: Speed Rotation



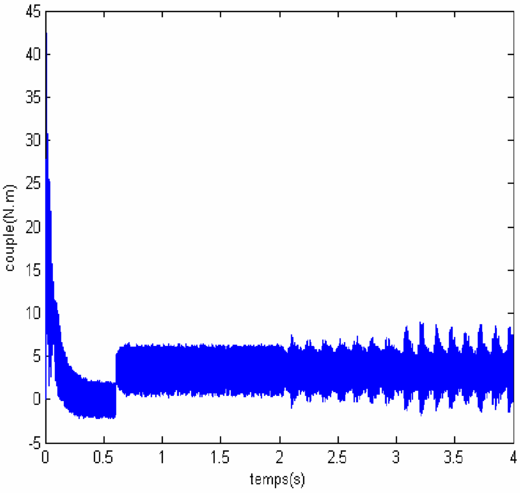
Enlarging of speed



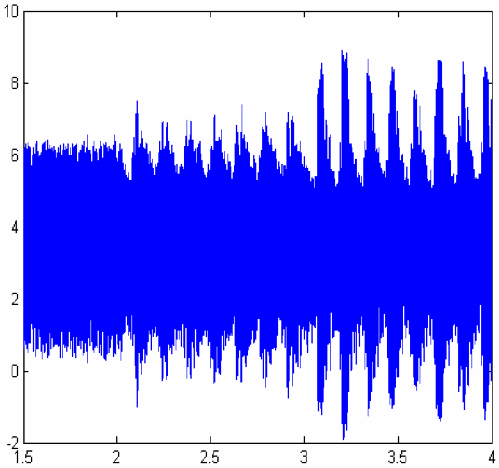
b: Stator current



Enlarging of current



c: Electromagnetic Torque



Enlarging of Torque

Figure.3. Simulation with the reduced model:
Machine loaded (Cr=3.5N.m)
with successive ruptures of the bars 1 after 2
starting from t=2s

V. CONCLUSION

Nous avons étudié dans cet article l'influence d'un défaut rotorique (rupture de barre) sur le courant statorique. L'association du modèle multi enroulements et celui de Park nous a permis de réaliser la simulation et le contrôle de la machine en présence (ou non) d'un défaut. En fait, la présence du défaut au rotor se traduit par des ondulations du couple électromagnétique. Nous avons abordé l'influence de la commande sur la réponse de la machine asynchrone qui présente des défauts rotoriques.

LIST OF SYMBOLS

Pn: nominal power 1.1 kw
V: tension of a stator phase 220 V
p: a number of pairs of poles 1
fs: stator frequency of tension 50 Hz
RS: resistance of a stator phase 7.58 Ω
Rr: resistance of the rotor cage 6.3 Ω
Lr: rotor inductance 0.1612H
Rb: resistance of the rotor bar 71.5µW
Le: inductance of leakages of ring 0.1µH
lsf: inductance of stator escapes 0,0265H
Lb: inductance of the rotor bar 0.1µH
Le: rotor inductance of ring 0.1µH
Lsc: stator cyclic inductance 0.5976H
Jm: moment of inertia 0.0054 Nms2
Re: resistance of ring of short-circuit 1.5µW
NR: a number of bars to rotor: 16
NS: a number of whorls per stator phase: 160
Bk: magnetic density of rotor flow
MSr: mutual inductance stator nets 26.5mH
g: slip
RbFK: additional resistance of defect of a rotor bar
ISn: running of the stator phases; n=1,2,3 (a number of phases)
a: electrical angle between two rotor meshs;adjacent: 0.3927
F_{cal}: calculated frequency

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