ASSOCIATE MODEL OF AN INDUCTION MOTOR FED BY A PWM INVERTER

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1. ABSTRACT

The present work will take into account the *MatlabSimulink* models of the induction motor, used for the work simulation of the induction motor in the dynamic regime. Another problem brought into discussion in this paper is the influence produced by the voltage from the voltage-source inverters upon the characteristics of the motor.

2. INTRODUCTION

Directly fed from the sine wave power source, the motor functions at a constant frequency end voltage. The inverter offers minimum frequency end variable voltage, the induction motor being able to operate in a large speed domain end produce interesting characteristics. The main disadvantage of using the induction motors coupled with inverters is represented by the presence of superior harmonics in the voltage inverters end the stator currents. These harmonics produce a deformant regime inside the motor, with effects upon the characteristics.

3. THE MATLAB_SIMULINK MODEL OF THE INDUCTION MOTOR

It is considered the induction motor with the rotor in short-circuit with the electrical end mechanical parameters benig constant, in a referential solidary with the stator. The magnetical loss is considered to be neglectable. The mathematical model is biult based on the written ecuations in the theory of the two-axis [1]. It is taken into account the case of the command in voltage.

In order to study the transitorious processes of practical interest, the voltage ecuations are used together with the mechanical ecuation of motion. The *MatlabSimulink* model is obtained by writing the ecuation of voltage with sizes referred to the stator under the form of state ecuation:

$$\frac{d}{dt}\begin{vmatrix} i_{sd} \\ i_{sq} \\ i'_{rd} \\ i'_{rq} \end{vmatrix} = \begin{vmatrix} L_{sd} & L_{mdq} & L_{md} & L_{mdq} \\ L_{mdq} & L_{sq} & L_{mdq} & L_{mq} \\ L_{md} & L_{mdq} & L'_{rd} & L_{mdq} \\ L_{mdq} & L_{mq} & L_{mdq} & L'_{rq} \end{vmatrix}^{-1} \cdot \begin{vmatrix} -R_s & 0 & 0 & 0 \\ 0 & -R_s & 0 & 0 \\ 0 & -\omega L_{sh} & -R'_r & -\omega L'_{r\sigma} \\ \omega L_{sh} & 0 & \omega L'_{r\sigma} & -R'_r \end{vmatrix} \cdot \begin{vmatrix} i_{sd} \\ i_{sq} \\ i'_{rd} \\ i'_{rq} \end{vmatrix} + \begin{vmatrix} L_{sd} & L_{mdq} & L_{md} & L_{mdq} \\ L_{mdq} & L_{sq} & L_{mdq} & L_{mq} \\ L_{md} & L_{mdq} & L'_{rd} & L_{mdq} \\ L_{mdq} & L_{mq} & L_{mdq} & L'_{rq} \end{vmatrix}^{-1} \cdot \begin{vmatrix} u_{sd} \\ u_{sq} \\ 0 \\ 0 \end{vmatrix}, \tag{1}$$

where R_s, R'_r are resistence of the stator per phase and resistence of the rotor referred to the stator per phase; u_{sd}, u_{sq}, i_{sd}, i_{sq}, i'_{rd}, i'_{rq} represent the projections of the stator voltage

$\underline{u}_s$ after the dq axis, the stator current $\underline{i}_s$, the rotor current referred to the stator $\underline{i}'_r$; L_s, L'_r represent the total stator and rotor inductance per phase, end L_{sd}, L_{sq}, L'_{rd}, L'_{rq} are the projections of L_s, L'_r on the axis dq; $L_{s\sigma}$, $L'_{r\sigma}$ are the stator leakage inductance per phase end the rotor leakage inductance referred to the stator per phase; L_{sh} is the main cyclical inductance; Ψ_{shd}, Ψ_{shq}, i_{md}, i_{mq} represent the projections of the complex vectors of the magnetical flux, respectively of the magnetical current after the axis dq; L_{mdq}, L_{mqd} are projections the mutual coupled inductance, end ω is the rotor speed.

The second matrix from the right side of the ecuation (1) is put under the following form:

$$\begin{vmatrix} -R_s & 0 & 0 & 0 \\ 0 & -R_s & 0 & 0 \\ 0 & -\omega L_{sh} & -R_r^{'} & -\omega L_{r\sigma}^{'} \\ \omega L_{sh} & 0 & \omega L_{r\sigma}^{'} & -R_r^{'} \end{vmatrix} = \begin{vmatrix} -R_s & 0 & 0 & 0 \\ 0 & -R_s & 0 & 0 \\ 0 & 0 & -R_r^{'} & 0 \\ 0 & 0 & 0 & -R_r^{'} \end{vmatrix} + \omega \cdot \begin{vmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & -L_{sh} & 0 & -L_{r\sigma}^{'} \\ L_{sh} & 0 & L_{r\sigma}^{'} & 0 \end{vmatrix} \tag{2}$$

The mechanical equation of motion is as follows:

$$\frac{d\omega}{dt} = \frac{p}{J} \cdot \left[\frac{3}{2} p L_{sh} \left(i_{sq} i_{rd}^{'} - i_{sd} i_{rq}^{'} \right) - M_R \right], \tag{3}$$

where M_R is the shaft mechanical torque, end J represents the moment of inertion.

Fig. 1. The SIMULINK block of the saturated induction motor.

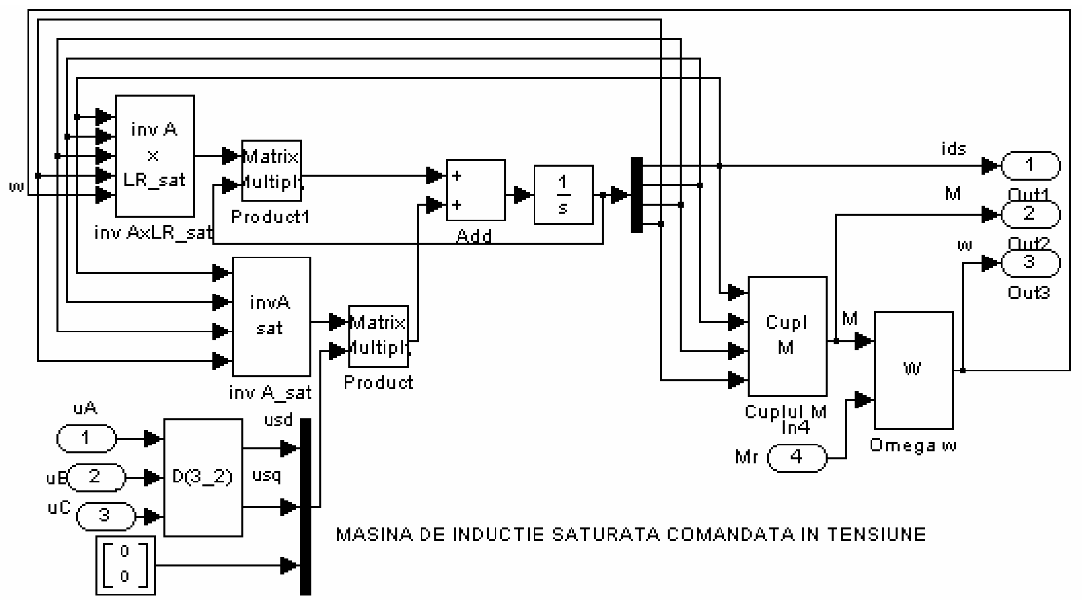


Fig. 2. The Simulink structure of the saturated induction motor.

The *SIMULINK* block from fig. 1 of the saturated induction motor is obtained on the base of ecuation (1), of matrix (2) end of ecuation (3), end has the structure from fig. 2.
The non saturated motor is obtained by being taken into consideration the static inductance equal with the differential inductance: $L_{sh}=L_{sht}$.

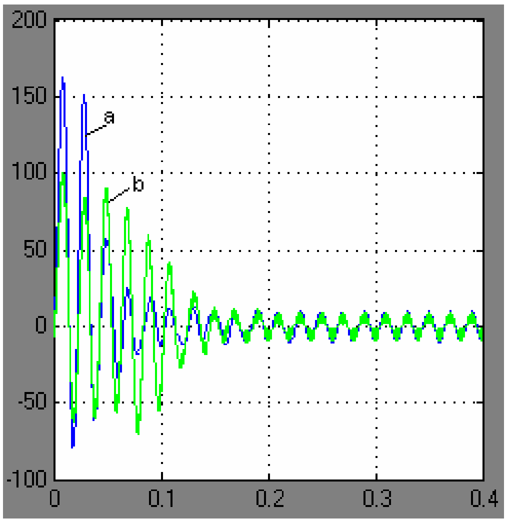
4. THE NUMERICAL SIMULATION OF THE FUNCTIONING OF THE INDUCTION MOTOR COUPLED WITH THE INVERTERS

In a dynamic regime, we analyse first of the phenomena from the induction motor fed by a PWM inverter, compared to the phenomena that appear at the feeding from the sine wave power source. The feeding voltage is $U=380\ V$ end frequency $f=50\ Hz$.

The squirred-cage induction motor analysed here has the parameteres defined as follows: $P_n=15\ Kw$; $U_n=380/660\ V$; $n=1500\ rot/min$; $f_{1n}=50\ Hz$; $R_s=0{,}817\ \Omega$; $L_{\sigma l}=0{,}0056\ H$; $R_r=0{,}7197\Omega$; $L'_{\sigma 2}=0{,}0084\ H$; $L_{sh}=0{,}1748\ H$; $p=2$; $J=0{,}0312\ Kgm^2$.

We obtain the $i_{ds}=f(t)$, $M=f(t)$, $\omega=f(t)$ from figures 3, 4 end 5 at the feeding of the motor from a sine wave source, respectively from a *PWM* inverter source.

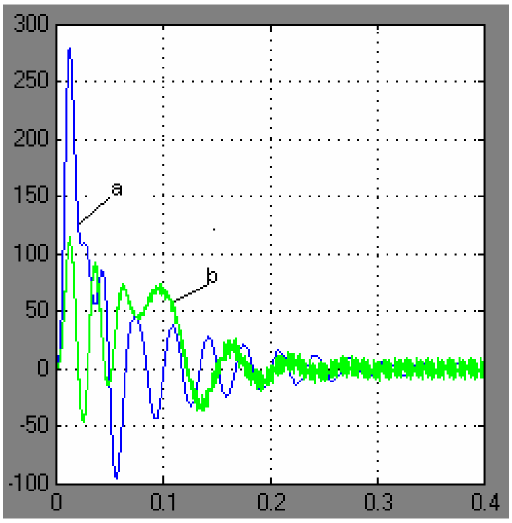
i_{ds} [A]



t [s]

Fig. 3. The characteristics $i_{ds}=f(t)$:
a. at the feeding from the sine wave source;
b. at the feeding from the inverter.

M [nm]



t [s]

Fig. 4. The characteristics M=f(t):
a . at the feeding from the sine wave source;
b. at the feeding from the inverter.

As a result of the feeding of the induction motor from the sine wave end *PWM* inverter, we can observe differences at currents, especially at the amplitude of the oscillations, end at the torque at amplitude and form. The differences influence the speed of the rotor $\omega(t)$, as well, fig.5.

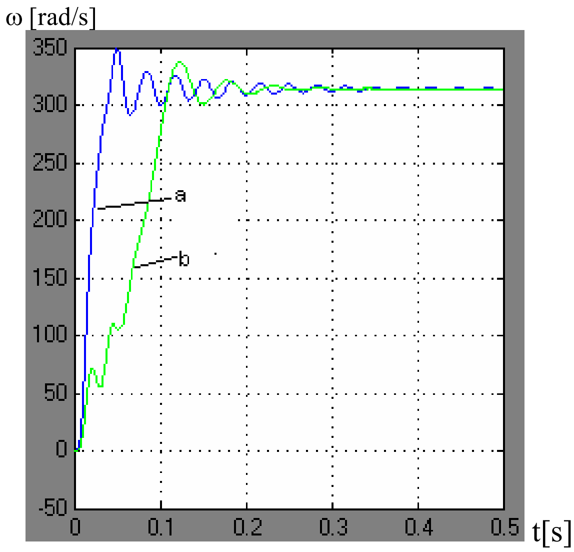


Fig. 5. The characteristics $\omega = f(t)$: a. at the feeding from the sine wave source;
b. at the feeding from the inverter source.

Next, there is an analysis of the influence of the saturation upon the characteristics of the induction motor fed by a *PWM* inverter. With the *SIMULINK* block from fig. 1, we get the 6, 7 end 8 figures, where is a comparative representation of the $i_{ds}=f(t)$, $M=f(t)$ end $\omega = f(t)$ characteristics for the cases: a) $L_{sh}=L_{sht}$; b) $L_{sh}\neq L_{sht}$.

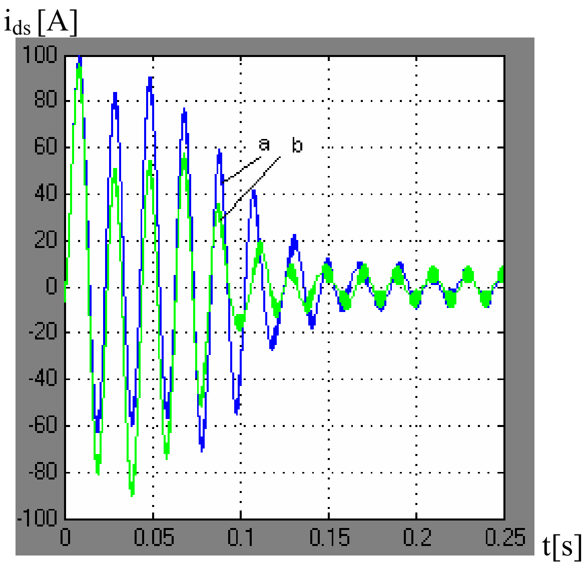


Fig. 6. The characteristics $i_{ds} = f(t)$: a. without considering the differential inductance;
b. with considering the differential inductance.

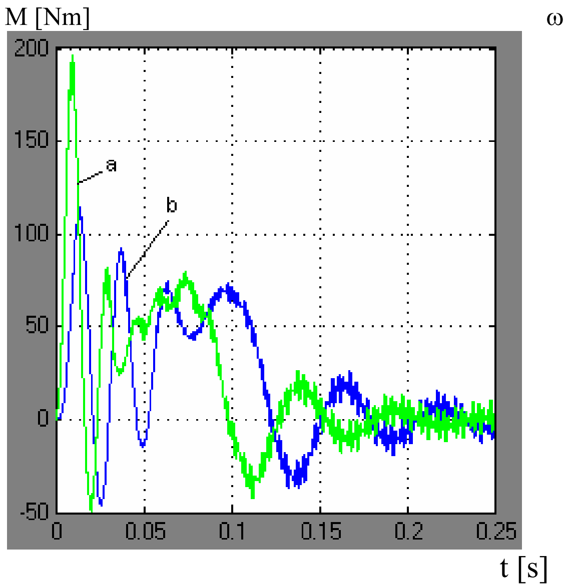


Fig. 7. The characteristics $M = f(t)$:
a. without considering the differential inductance;
b. with considering the differential inductance.

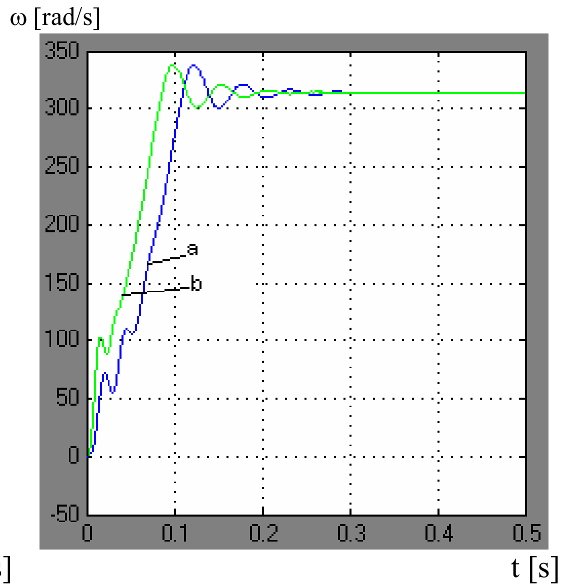


Fig. 8. The characteristics $\omega = f(t)$:
a. without considering the differential inductance;
b. with considering the differential inductance.

The motor used for the simulation has a static inductance *Lsh=0.1748 H* end the differential inductace *Lsht=0.1H.* The differential inductace introduces oscillations of the sizes with a higher amplitude. This phenomenou is obvious especially in the curve of the electromagnetical torque, depending on the start time, too. The execution time of the scheme that doesn't take into consideration the saturation is less. We obtain a better aproximation of the evolution in time of the phenomena at the saturation consideration.

5.CONCLUSIONS

When feeding the induction motor from the *PWM* inverters, there exists a high amplitude of the currents end torque oscillations, the form of the torque is changed, these influencing the speed of the motor. The differential inductance introduces oscillations with higher amplitudes. The magnetical saturation influences the skin-effect end invert effect.

6. REFERENCES

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