TWO-PHASE INDUCTION MACHINE BEHAVIOR AT TRANSIENT REGIME RUNNING

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Abstract: In this paper is realized the modeling and simulation of a two-phase induction machine at transient regime running. The simulation model is verified on a machine with known parameters and it consists of modification of some main parameters (the stator and rotor resistance). There are determined the electromagnetic torque and revolution variation with time. It is described also a way of adapting the two-phase model dq-dq of the machine for implementation in the Matlab-Simulink.

Keywords: mathematical models, simulation, transient analysis, two-phase induction motors

1. INTRODUCTION

The two-phase induction machine has had a reduced use due to the absence of a two-phase network and to the difficulty to create a symmetrical two-phase system having the existent three-phase or one-phase networks as base. In the conditions of induction machines fed from static converters in systems of controlled electrical drives it may be used the three-phase induction machine as well as the two-phase machine. Much more, having just two phases to be fed the power electronic converter's inverter becomes more simple having just two sides and having a similar complexity with the direct variable voltage regulator with four quadrants.

In this paper is realized the simulation in transient regime of a two-phase induction machine (MAB) that has all the technical characteristics already known (Crăciunaş, 2002). The simulation consists of modification of some main parameters (the stator and rotor resistance) and is presented also ways of adapting the two-phase model dq-dq of the machine for implementation in the Matlab-Simulink. Starting from the voltage equations is being built the repetitive diagram corresponding to the two-phase model of the induction machine (Dordea, 1993). In this case we have to deal with a natural model which practically keeps unchanged the stator winding parameters.

2. THE LINEAR MODEL OF MAB USED IN MATLAB-SIMULINK SIMULATION

The most adequate model is that which offers the simplest structure of the control system. If for the three-phase induction machine (MAT), the most appropriate model, that is capable of solving the machine and control problems, is based on the spatial vector theory (Măgureanu, 1980), MAB is built such as the mathematical model is also physically realized. For this machine the two-phase concept is improved namely the unitary theory of electrical. If for MAT the d-q sizes are only mathematical for MAT they are also physically. The d-q currents and voltages appear in field oriented control loops, outside the machine, while the fluxes appear physically in the machine's air gap, where they can be directly measured.

The feeding voltage applied to each phase is balanced by the terminal voltage drop over the phase's resistance and by the induced electromotive force produced by the correspondent magnetic flux.

So the stator (1) and rotor (2) voltage relations corresponding to the two-phase model, written in matrix form are,

$$[U_S] = R_S \cdot [i_S] + \frac{d}{dt}[\Psi_S] \quad (1)$$

$$0 = R_R \cdot [i_R] + \frac{d}{dt}[\Psi_R] \quad (2)$$

Taking into account that after this we intend to do the studying of converter assembly MAB, the most appropriate system of reference is the one tied to the stator because it assures the representation in natural sizes of the feeding current and voltage. For this situation the decomposed voltage equations in components made by the two orthogonal axes d and q, take the form,

$$\begin{aligned} U_d &= R_S \cdot i_d + \frac{d\Psi_d}{dt} \\ U_q &= R_S \cdot i_q + \frac{d\Psi_q}{dt} \\ 0 &= R_R \cdot i_D + \frac{d\Psi_D}{dt} + \cdot\omega\cdot\Psi_Q \\ 0 &= R_R \cdot i_Q + \frac{d\Psi_Q}{dt} - \cdot\omega\cdot\Psi_D \end{aligned} \quad (3)$$

where the machine's flux equations have the form

$$\begin{aligned} \Psi_d &= L_{S\sigma} \cdot i_d + M \cdot (i_d + i_D) \\ \Psi_q &= L_{S\sigma} \cdot i_q + M \cdot (i_q + i_Q) \\ \Psi_D &= L_{R\sigma} \cdot i_D + M \cdot (i_d + i_D) \\ \Psi_Q &= L_{R\sigma} \cdot i_Q + M \cdot (i_q + i_Q) \end{aligned} \quad (4)$$

The two-phase model used in the simulation of the two-phase induction machine behavior through the Simulink simulator is based on the set of equations (3). The equations form is adjusted to the Simulink's special case of solving a set of equations. This way, the program becomes compact and the simulation time is dramatically reduced. The sizes calculated after the simulation are the stator and rotor current and flux varying with each considered axis. The feeding voltage of the two stator windings is considered as input. Replacing (4) in (3) we get,

$$\begin{aligned} U_d &= R_S i_d + L_{\sigma S}\frac{di_d}{dt} + \frac{d}{dt}[M(i_d + i_D)] \\ U_q &= R_S i_q + L_{\sigma S}\frac{di_q}{dt} + \frac{d}{dt}[M(i_q + i_Q)] \\ 0 &= R_R i_D + L_{\sigma R}\frac{di_D}{dt} + \frac{d}{dt}[M(i_d + i_D)] + \omega L_{\sigma R} i_Q + \omega M(i_q + i_Q) \\ 0 &= R_R i_Q + L_{\sigma R}\frac{di_Q}{dt} + \frac{d}{dt}[M(i_q + i_Q)] - \omega L_{\sigma R} i_D - \omega M(i_d + i_D) \end{aligned} \quad (5)$$

system in which, if we don't take into account the saturation, the induction M is constant.

This is the classical form of voltage equations that stays as base for the repetitive diagram corresponding to the two-phase model of an induction machine.

In this form it can be simulated in Matlab-Simulink the electromagnetic part behavior of MAB in permanent or transient regime, knowing the rotor rotation speed ω. For a complete description we have to add the equations that describe the mechanical sizes, respectively the electromagnetic torque expression and the movement equation. The electromagnetic torque expression particularized for the fix reference system related to the stator and using the d and q components is,

$$T = p \cdot (\Psi_{Sd} i_{Sq} - \Psi_{Sq} i_{Sd}) \quad (6)$$

The movement equation is,

$$T - T_r = J \cdot \frac{d\omega}{dt} + F_S \cdot \omega \quad (7)$$

where T_r is the load torque, J is the total moment of inertia and F_S is the dense friction coefficient.

In this paper it was made the simulation for a two-phase induction machine with the following main parameters,

$P_n = 35W$;	$U_{1n} = 230V$;	$R_S = 415\Omega$;
$f_{1n} = 50Hz$;	$n_{1n} = 1500 rot/\min$;	$R_R = 295{,}72\Omega$;
$Z_S = 16$;	$Z_R = 17$;	
$p = 2$;	$J = 3{,}3 \cdot 10^{-5} Kg \cdot m^2$;	

It has been simulated the transient regime at the no-load start of the machine that is fed with a nominal voltage of 230V, for different values of the stator and rotor resistances. The simulated transient process time (0.5s) assures the reach of the stabilized regime of constant revolution, 314 rad/s.

Block diagram that is the base for this simulation is presented in Figure 1, realized in development environment Matlab-Simulink. The feeding voltages U_d and U_q have the amplitude $230 \cdot \sqrt{2}$ and staggered with $\pi/2$ one against the other.

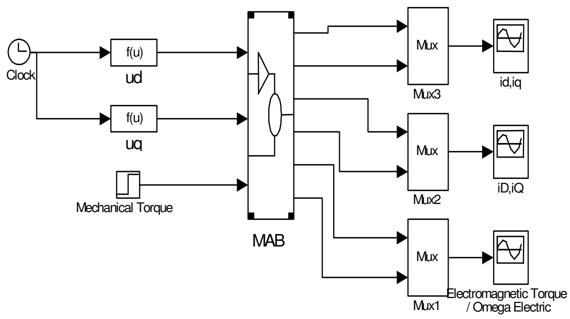


Fig. 1. Block diagram used in simulation

So, after a period of transient regime in which the values of the characteristic sizes stabilize, MAB enters in a permanent regime, of constant torque and revolution. All the values from equivalent circuit become sinusoidal under the influence of the stator feeding voltage. In Figure 2 is the MAB block, where are implemented the voltage (5) and the movement (7) equations of the machine.

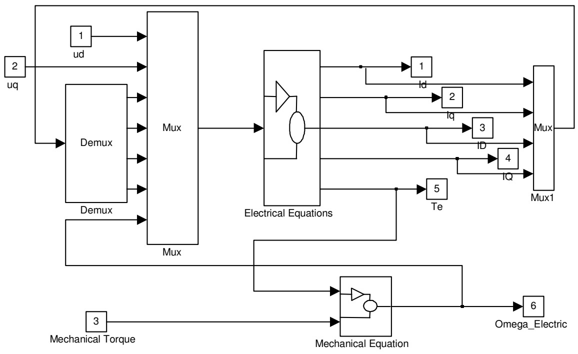


Fig. 2. MAB block diagram

The set of equations is non-linear because are to be noted multiplications between variables. The parameters have been supposed constant, without taking into account the magnetic circuit saturation, neither the coupling phenomenon between axes.

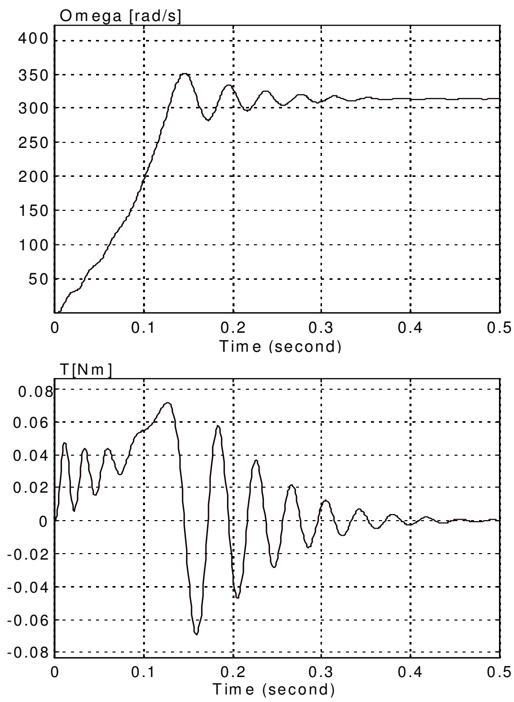


Fig. 3. Transient regime for $R_1 = 415\Omega$

Figure 3 presents the variation in time of mechanical sizes, the rotor's angular speed and electromagnetic torque, characteristics obtained for the main input values calculated through the classic methods (Crăciunaş, 2002). So, for an enlarged stator resistance ($R_1 = 500\Omega$) and constant rotor resistance ($(R_R = 295{,}72\Omega)$), can be observed some essential modifications of the variations in time for the machine's electromagnetic torque and revolution, Figure 4.

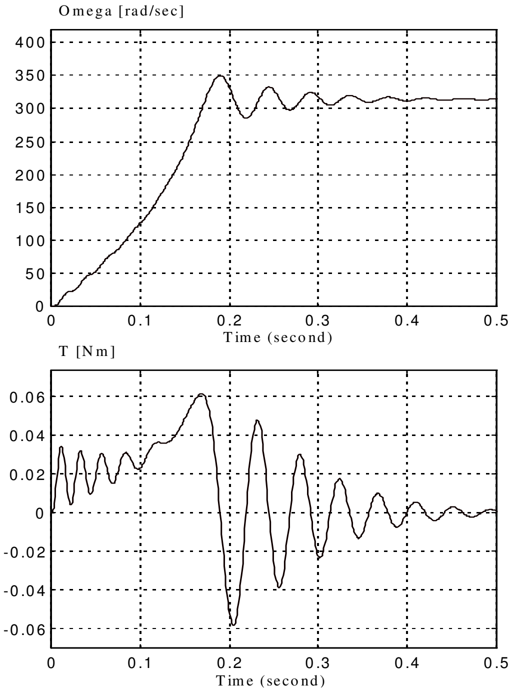


Fig. 4. Transient regime for $R_1 = 500\Omega$

Comparative to the first done transient regime, in which $R_1 = 415\Omega$, this simulation brought to the system a delay in the stabilization process and also a smaller maximum value of the electromagnetic torque.

Another case studied on the same model is for $R_S = 345\Omega$, a smaller value than the prescribed value. This time we observe a stabilization of the transient process much faster (0.3s) than the previous case, but also a much bigger value of the maximum electromagnetic torque, Figure 5.

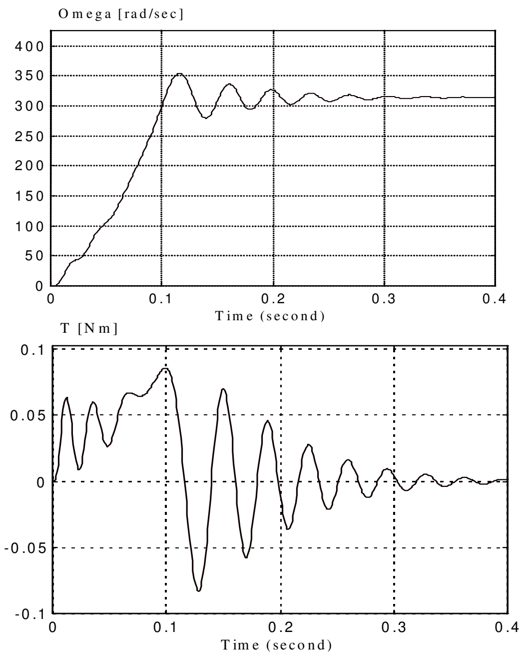


Fig. 5. Transient regime for $R_S = 345\Omega$

Another main size which can influence these characteristics is the rotor resistance. Keeping constant the stator resistance $R_S = 415\Omega$, for a rotor resistance of $R_R = 320\Omega$, the machine's mechanical and electromagnetic processes evolve much faster. The simulated transient process duration, (0.3s) assures the achievement of stabilized regime, of constant revolution and electromagnetic torque with a variation, Figure 6.

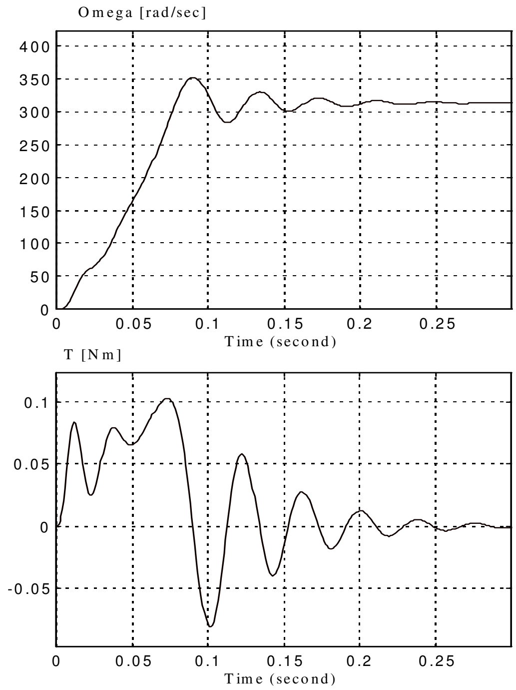
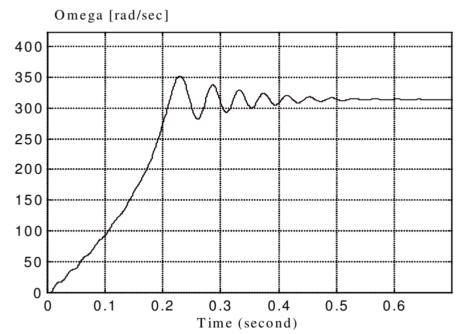


Fig. 6. Transient regime for $R_R = 320\Omega$

Not the same thing can be said if the rotor resistance is decreased to a smaller value than the prescribed one, $R_R = 250\Omega$. The characteristics will be in a negative way influenced, the transient processes developing through a much longer period than in the precedent case. The duration of the simulated transient process assures the achievement of stabilized regime, of constant revolution after 0.6s and electromagnetic torque with a variation, Figure 7.



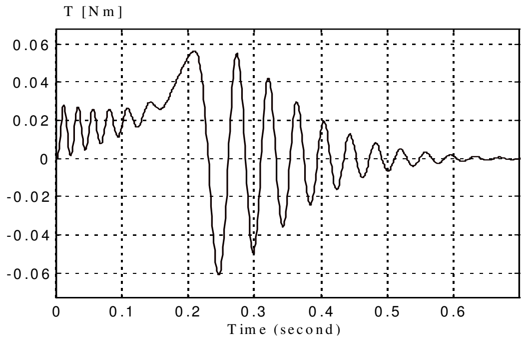


Fig. 7. Transient regime for $R_R = 250\Omega$

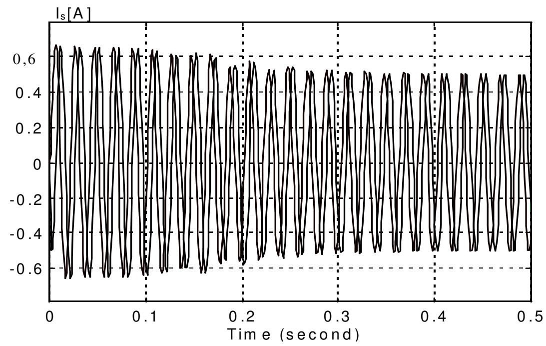


Fig. 8. Stator current in transient regime

3. CONCLUSIONS

After numerous attempts effectuated on the proposed model the following conclusions can be drawn:

1. The attainment of a stabilized regime, of constant revolution, is assured much faster for smaller values for the stator resistance, respectively, bigger values for the rotor resistance, than the prescribed ones.

2. The value of the stator current for the stabilized regime is not influenced by the values of the two resistances, so for all the effectuated attempts in this paper, the stator current has stabilized itself at 0.5A, Figure 8.

REFERENCES

Crăciunaş, G. (2002). *Studiul maşinilor bifazate de curent alternativ în regim de motor*. Teză de doctorat, Universitatea Tehnică din Cluj-Napoca.

Dordea, T. (1993). La théorie des deux axes pour les machines électriques enroulement répartis par zone. *Rev. Roumaine Sci.Techn. – Electrotechn. et Energ.*, **Vol.38, No.2**, pp.235-255.

Măgureanu, R. (1980). *Maşini electrice speciale pentru sisteme automate*. Editura Tehnică, Bucureşti.