COMPUTER MODEL OF THREE PHASE MOTOR

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The proposed paper presents a model of an induction motor. It calculates two flux linkage – in rotor Ψ_r and in the stator Ψs,, electromagnetic torque M_m,, frequency of rotation ω_r and the sliding - s on the base of other known parameters such as the inductance in rotor L_r and in stator L_s, the mutually inductance L_m, the active resistance in the stator R_s, the number of pole pairs Z_p and the moment values of the voltages and the currents from two of the phases supply . The present work is based on fundamental moments from the theory of the electromotion. The model is designed to accomplish the system for regulation of an induction motor by the orientation of the magnetic field. The development is made with the help of MATLAB (SIMULINK).The investigations are made with the parameters of real motor and the results are shown in a graphic form.

It is known that the dynamics of the machine are generally described by four equations of the electric balance in the circuits of the stator and the rotor [2] :

(1) $U_{s\alpha} = R_s.i_{s\alpha} + \dfrac{d\Psi_{s\alpha}}{dt}$

(2) $U_{s\beta} = R_s.i_{s\beta} + \dfrac{d\Psi_{s\beta}}{dt}$

(3) $0 = R_r.i_{r\alpha} + \dfrac{d\Psi_{r\alpha}}{dt}$

(4) $0 = R_r.i_{r\beta} + \dfrac{d\Psi_{r\beta}}{dt}$ `

The symbols are as follows:

$U_{s\alpha}$ and $U_{s\beta}$ - components longitudinal and transverse of the voltage in the stator
U_{rd} and U_{rq} - components longitudinal and transverse of the voltage in the rotor
$i_{s\alpha}$ and $i_{s\beta}$ - components longitudinal and transverse of the current in the stator
i_{rd} and i_{rq} - components longitudinal and transverse of the current in the rotor
R_s and R_r – active resistances in the stator and in the rotor
$d\Psi_{s\alpha}/dt$ - derivative of the component longitudinal of the flux of the stator
$d\Psi_{s\beta}/dt$ – derivative of the component transverse of the flux of the stator
$d\Psi_{rd}/dt$ - derivative of the component longitudinal of the flux of the rotor
$d\Psi_{rq}/dt$ – derivative of the component transverse of the flux of the rotor

Besides these equations, Ψ_s and Ψ_r are described by the system below:

(5) $\Psi_{s\alpha} = L_s.i_{s\alpha} + L_m.\cos\varphi_{ел}.i_{rd} - L_m.\sin\varphi_{ел}.i_{rq}$

(6) $\Psi_{s\beta} = L_s.i_{s\beta} + L_m.\sin\varphi_{ел}.i_{rd} + L_m.\cos\varphi_{ел}.i_{rq}$

(7) $\Psi_{rd} = L_m.\cos_{ел}.i_{s\alpha} + L_m.\sin\varphi_{ел}.i_{s\beta} + L_r.i_{rd}$

(8) $\Psi_{rq} = -L_m.\sin_{ел}.i_{s\alpha} + L_m.\cos\varphi_{ел}.i_{s\beta} + L_r.i_{rq}$, where

$\varphi_{ел}$ – is the angle between Ψ_s and Ψ_s

It calculates of (9). [3]

(9) $$\varphi_{ел} = \frac{L_m^2}{(L_s.L_r - L_m^2).L_s}$$

The electromagnetic torque is defined by expression (10). [1]

(10) $$M_m = Z_p.L_m.(i_{s\beta}.i_{rd} - i_{s\alpha}.i_{rq}).\cos\varphi_{ел} - \\ -(i_{s\beta}.i_{rd} + i_{s\alpha}.i_{rq}).\sin\varphi_{ел}$$

If it is accepted that the system is completely symmetric, then by measuring the voltages and the currents in two of the phases supply, all those unknowns that we spoke at the beginning can be obtained. For that purpose, from the known voltages and currents it is possible to calculate the similar from the phase of the third. After that, the supply transforms in two-phase co-ordinate system by means of equations (11) and (12). [1]

(11) $$X_{1\alpha} = \sqrt{\frac{2}{3}}(X_{1a} - \frac{1}{2}X_{1b} - \frac{1}{2}X_{1c})$$

(12) $$X_{1\beta} = \sqrt{\frac{2}{3}}(\frac{\sqrt{3}}{2}X_{1b} - \frac{\sqrt{3}}{2}X_{1c}),$$

where a, b and c are the three phases.

In substituent values of $U_{s\alpha}$, $U_{s\beta}$, $I_{s\alpha}$ and $I_{s\beta}$ in (1) and (2), it is possible to find $d\Psi_{s\alpha}/dt$ and $d\Psi_{s\beta}/dt$.

After integrating the two parts separately, come out $\Psi_{s\alpha}$ and $\Psi_{s\beta}$. In this way expression (13) defines the absolute value of the flux of the stator :

(13) $$|\Psi_s| = \sqrt{\Psi_{s\alpha}^2 + \Psi_{s\beta}^2}$$

Then from expression (5) defines I_{rq} and becomes (14):

(14) $$i_{rq} = \frac{L_s.i_{s\alpha} + L_m.\cos\varphi_{ел}.i_{rd} - \Psi_{s\alpha}}{L_m.\sin\varphi_{ел}}$$

In substituent (14) in (6) obtains (15):

(15) $$i_{rd} = \frac{\sin\varphi_{ел}(\Psi_{s\beta} - L_s.i_{s\beta}) + \cos\varphi_{ел}(\Psi_{s\alpha} - L_s.i_{s\alpha})}{L_m}$$

After combinating of (14) and (15), and simplificating the expression, i_{rq} receives the following:

(16) $$i_{rq} = \frac{\sin\varphi_{ел}(L_s.i_{s\alpha} - \Psi_{s\alpha}) - \cos\varphi_{ел}(L_s.i_{s\beta} - \Psi_{s\beta})}{L_m}$$

On the base of the values of $i_{s\alpha}$, $i_{s\beta}$, i_{rd} and i_{rq}, it can be obtained Ψ_{rd} and Ψ_{rq} from (17) and (18):

(17) $$\Psi_{rd} = L_m.(\cos\varphi_{ел}.i_{s\alpha} + \sin\varphi_{ел}.i_{s\beta}) + \cos\varphi_{ел}.\sin\varphi_{ел}. \\ .(\Psi_{s\beta} - L_s.i_{s\beta}) + \cos^2\varphi_{ел}(\Psi_{s\alpha} - L_s.i_{s\alpha})$$

$$\Psi_{rq} = L_m(\cos\varphi_{ел}.i_{s\beta} - \sin\varphi_{ел}.i_{s\alpha}) +$$
$$(18) \quad + \frac{L_r}{L_m}\left[(\sin\varphi_{ел}(L_s.i_{s\alpha} - \Psi_{s\alpha}) - \cos\varphi_{ел}(L_s.i_{s\beta} - \Psi_{s\beta})\right]$$

The rotational frequency of the rotor ω_r is defined by expression (19)

$$(19) \quad \omega_r = \int \frac{Z_p}{\sum J}.(M_m - M_w)dt \text{ , where}$$

Σ J- is the torque general of inertia
M_w – is the torque statical
M_m – is the torque electromagnetic
Z_p – is the number of pairs of poles

On the basis of the explained theory, a model of electrical motor is created. It is shown on fig.1

At the beginning from the measured values of the voltages and currents from two of the phases, are calculated the similar ones in the phase “w”. After that, the supply transforms in two phase co-ordinate system. Then by using the values obtained, it is possible to calculate $d\Psi_{s\alpha}/dt$, $d\Psi_{s\beta}/dt$, $|\Psi_s|$ and all others unknowns.

By knowing M_w, Z_p and M_m from (20) is defined the sliding – s

$$(20) \quad s = 1 - \frac{n.Z_p}{60.f} \text{ , where f – is the frequency of the voltage supply}$$

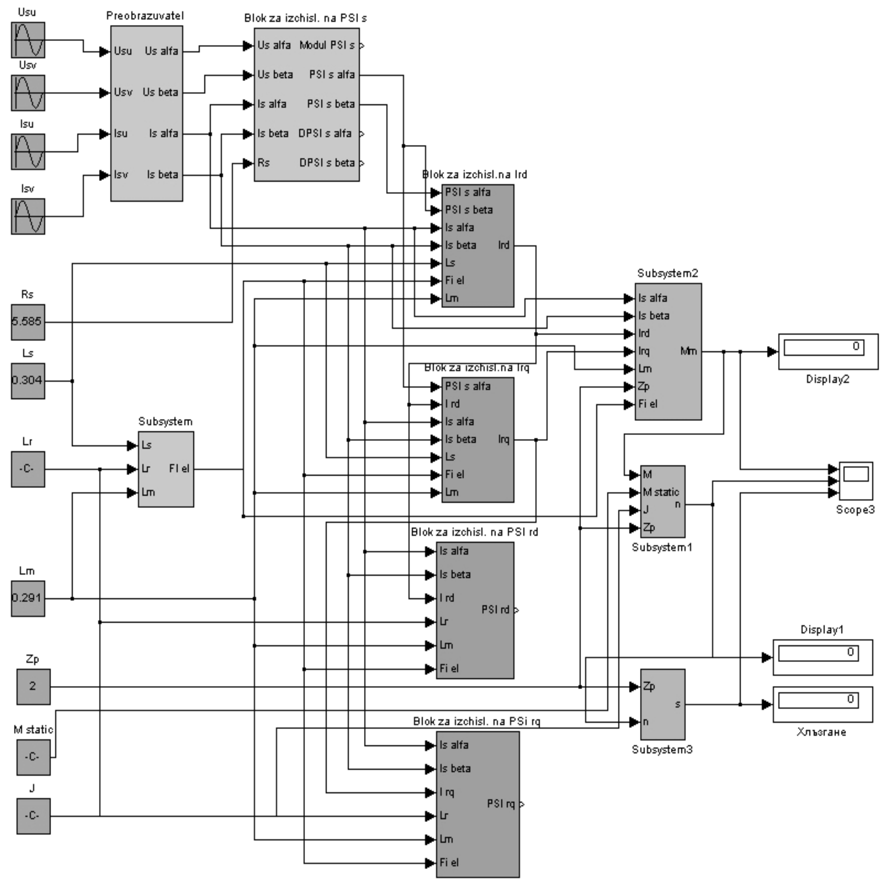

Fig.1. Model of electric motor

The investigations are made with the parameters of real motor. They are shown below:

P_{nom} = 1,5kW L_m= 0,291 H
U_{nom} = 220V L_s= 0,304 H
I_{nom} = 3,8 A L_r= 0,3066 H
M_m=10,23 N.m Z_p= 2
J = 0,00278 kg.m^2 n=1400rpm

On the base of data to the top, the results of the investigations with the model are watches below. The simulations are made for 10 sec. The form and the values of voltages and currents are presented on fig.2 and fig.3

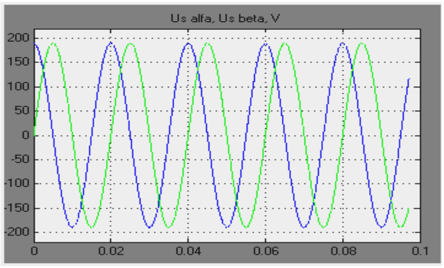

Fig.2. $\alpha - \beta$ components of the voltage in the stator U_s

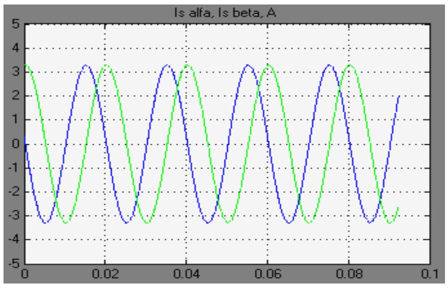

Fig.3 $\alpha - \beta$ components of the current in the stator

For the investigated motor, the components of the current in the rotor I_r are presented on Fig.4 below:

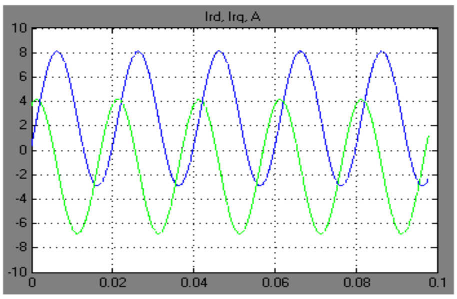

Fig.4 d-q components of the current in the rotor I_r

The mode of the fluxes in the stator and in the rotor is shown in fig.5 and fig.6

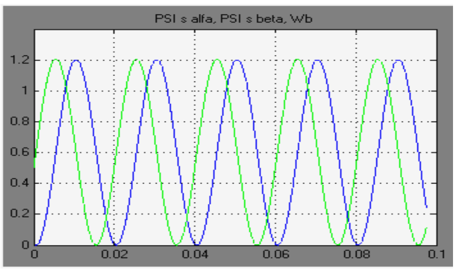

Fig.5 $\alpha - \beta$ components of the flux in the stator

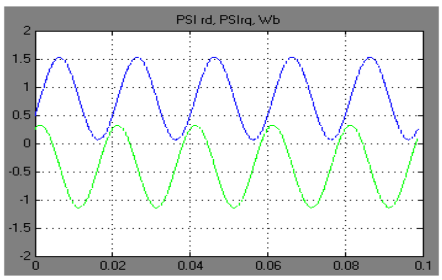

Fig.6 d-q components of the flux in the rotor

The results received from the model are presented on fig. 7 below.
The investigations are made for 10sec by nominal load of the motor. The torque calculated from the model was M_m=10,30 N.m. The torque static in the model was M_w=10,12 N.m. It represents 98% from the torque of the motor M_m. By this load the revolutions are n = 1400 rpm.
At the beginning it can see that the sliding – s is 1. For that time M_m is smaller than M_w. After the process of transition (t = 0,033sec.) M_m becomes bigger than M_w. From this moment the revolutions become n=1399 rpm and the sliding s = 0,067.

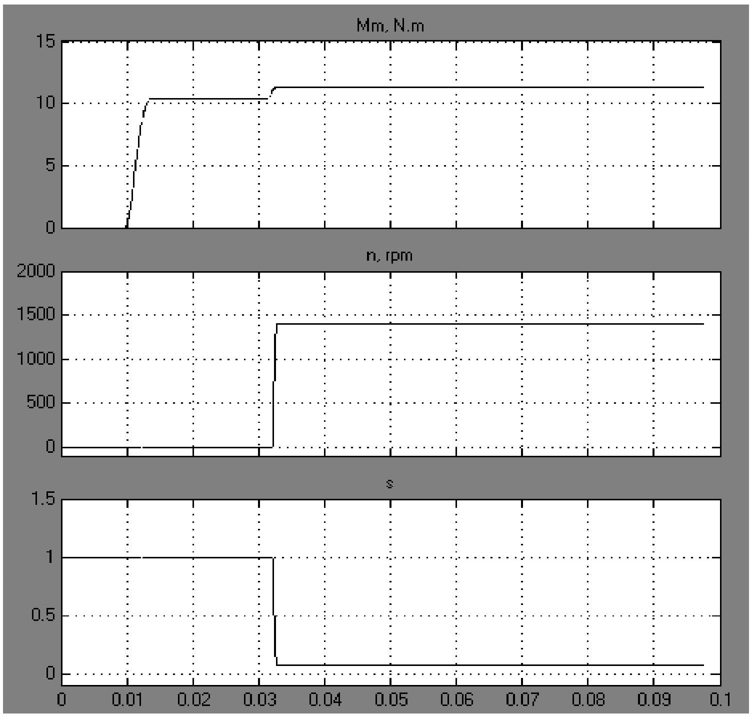

Fig. 7 Results from the investigations

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