INVESTIGATION OF A COMPUTER MODEL OF THREE-PHASE MOTOR REGULATED BY FREQUENCY MODE

Dinko Petkov Gospodinov, Pencho Venkov Georgiev

TU-Gabrovo 5300, H.Dimitar str. №4, Department of Electronics, e-mail: d.gospodinov@mail.bg, pencho_georgiev2001@yahoo.com, phone: 088/7 53 61 65

The article shows results made with a computer model of three-phase induction motor by regulation of a frequency of the voltage supply. It calculates two flux linkage- in a stator Ψ_s and in a rotor Ψ_r, revolutions per minute- n, torque electromagnetic – M, sliding- s and other parameters. These calculations are made with the help of two passing voltages and currents, measured in two of the phases in a stator. The model is designed for creation of a system for vector control and control by regulation of the field magnetic of three phase motors with the help of software product MATLAB (SIMULINK). It is synthesized on the base of fundamental moments from the theory of the electromotion.

In the last years of twentieth century, the electromotions received a significant progress. This is due to the appearance and development of two methods for regulation. They are vector control and control by regulation of the magnetic field. The systems for that regulation are designed on DSP devices. They produce the signals on the base of software built in the processor. Usually this is a computer model of the investigated induction motor. The present article shows the development of a model of three-phase induction motor. It is created by fundamental moments from the theory of electromotion.

It is known that the electrical balance in the circuit in the stator is described by the equations below:

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

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

where $U_{s\alpha}$ and $U_{s\beta}$ are components longitudinal and transverse of the voltage in the stator

$i_{s\alpha}$ and $i_{s\beta}$ - components longitudinal and transverse of the current in the stator

R_s – active resistance in the stator

$d\Psi_{s\alpha}/dt$ - 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

Besides (1) and (2), Ψ_s and Ψ_r are described by a system of equations shown from (3) to (6):

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

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

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

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

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

It calculates from (9). [3]

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

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

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

On the base of this short theory, is made a computer model of three-phase induction motor shown in fig.1. It calculates two fluxes-linkage in the stator Ψ_s and in the rotor Ψ_r, electromagnetic torque M, revolutions per minute- n, sliding- s and other parameters.

If it is accepted that the system is completely symmetric, then by measuring of two voltages and the currents in two of the phases supply, it is possible to obtain all those unknowns that we spoke at the beginning. For that purpose, from the known voltages and currents it can be calculated 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) $X_{1\alpha} = \sqrt{\dfrac{2}{3}}(X_{1a} - \dfrac{1}{2}X_{1b} - \dfrac{1}{2}X_{1c})$

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

The model is investigated by frequency mode of regulation of the type U/f=const. The investigations are shown with the parameters of three real motors, made in „ELMA-LTD" Troian. They are presented below:

ASM- 1

$P_н$ = 1,5 kW

$I_{н\,eff}$ = 3,8 A

$U_{н\,eff}$ = 220V/50Hz

J = 0,00278 N.m
Z_p = 2
Mm = 10,23 N.m
n = 1400 rpm
R_s = 5,585 Ω
R_r = 4,220 Ω
X_s = 4,060 Ω
X_r = 4,909 Ω
X_m = 91,49 Ω

ASM-2

$P_н$ = 2.2 kW
$I_{н\ eff}$ = 5.314 A
$U_{н\ eff}$ = 220V/50Hz
J = 0,00278 N.m
Z_p = 2
Mm = 15,036 N.m
n = 1400 rpm
R_s = 3,614 Ω
R_r = 2,874Ω
X_s = 3,4226 Ω
X_r = 3,6738 Ω
X_m = 73.3504 Ω

ASM-3

$P_н$ = 500W
$I_н$ = 2.9 A
$U_н$ = 127V/50Hz
J = 0,00095 N.m
Z_p = 2
Mm = 3,41
n = 1400 rpm
R_s = 4,495 Ω
R_r = 5,365 Ω
X_s = 5,024 Ω
X_r = 4,082 Ω
X_m = 51,81 Ω

The simulations are made for 10sec. The results from the experiments concern regulation from 100% to 60%. They can be seen in the tables bellow:

Table 1. Results for ASM-1

%	100%	90%	80%	70%	60%
U, V	155	139,5	124	108,5	93
I, A	2,685	2,670	2,644	2,6116	2,579
ω, rad^{-1}	314	282,6	251,2	219,8	188,4
f, Hz	50	45	40	35	30
M, N.m	10,50	10,51	10,50	10.50	10.50
Mw, N.m	10,295	10,295	10,295	10,295	10,295
n, rpm	1389	1219	1023	714	417

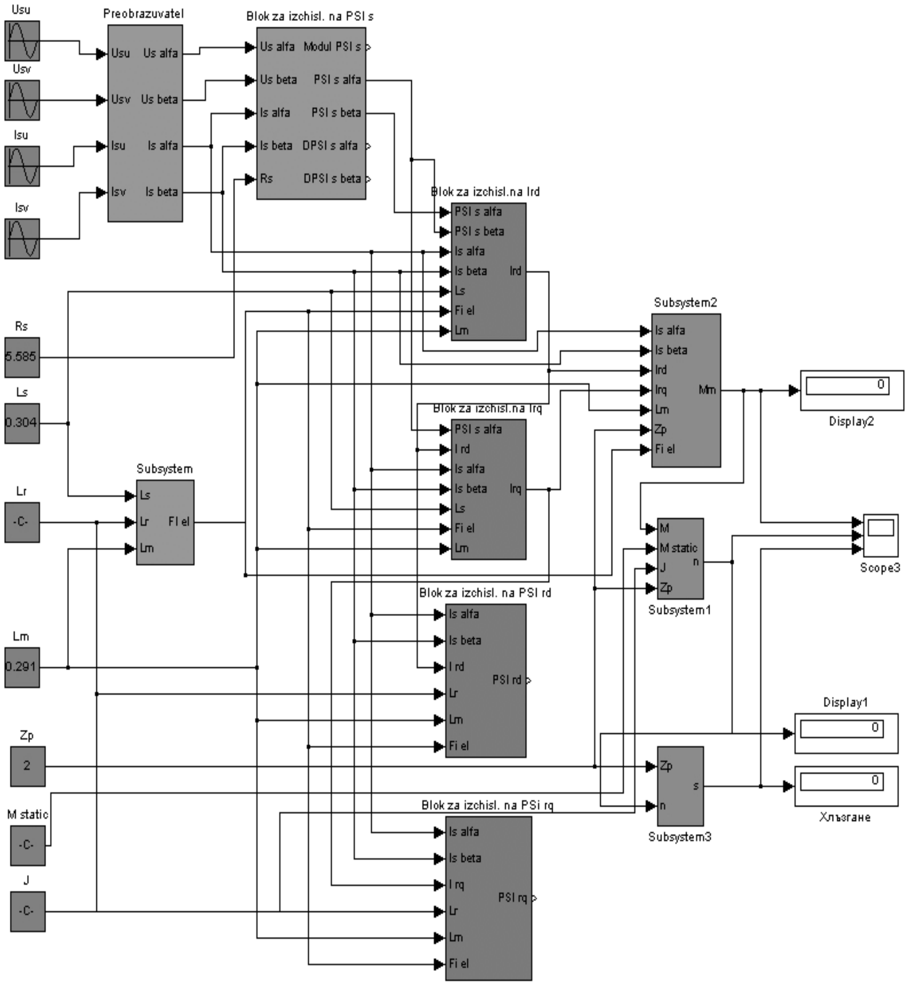

Fig.1. Model of electric motor

Table 2. Results for ASM-2

%	100%	90%	80%	70%	60%
U, V	155	139,5	124	108,5	93
I, A	3,7580	3,7345	3,7052	3,6680	3,6205
ω, rad^{-1}	314	282,6	251,2	219,8	188,4
f, Hz	50	45	40	35	30
M, N.m	15,08	15,08	15,08	15,08	15,08
Mw, N.m	14,8756	14,8756	14,8756	14,8756	14,8756
n, rpm	1404	1293	999	711	396

Table 3. Results for ASM-3

%	100%	90%	80%	70%	60%
U, V	90	81	72	63	54
I_s, A	2,05	2,041	2,0295	2,0133	1,980
ω, rad^{-1}	314	282,6	251,2	219,8	188,4
f, Hz	50	45	40	35	30
M, N.m	3,288	3,288	3,288	3,288	3.401
Mw, N.m	3,219	3,219	3,219	3,219	3,219
n, rpm	1386	1305	1010	717	409

In the tables it can be seen how with diminution of the voltage and the frequency, the revolutions per minute decrease too. Simultaneously, the electromagnetic torque M and the current I_s stay permanent. These high degree results show the adequacy of the model. With its help, there are made investigations by loading with static torques dependent from the frequency of rotation of the rotor. The received results are highly precised.

On the base of the synthesized model it will be create a system for vector control and control by regulation of the magnetic field.

References:

[1] Kluchev. V. Theory of electromotion. Technics 1989.
[2] Georgiev.P.V. Electronic regulators for electromotion, Gabrovo 1999.
[3] Rudakov.V.V.Asynchronous electromotions with vector regulation, Sanktpeterburg 1987.
[4] Vladimirov.P, Spirov. D., Rachev. Sv. Mode for sensorless speed determination of the rotor at the asynchronous electromotions.International scientific conference Gabrovo,2003.
[5] Nenov. N., Klissarov.G. „Electrical machines", Technics1979.