TWO-PHASE INDUCTION MOTOR WITH VECTORIAL ADJUSTING CONTROL SYSTEM USING ADAPTIVE METHODS FOR ROTOR FLUX ESTIMATION

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Abstract **– In this paper it is presented the simulation of a vectorial adjusting control system for a two-phase induction motor (TPIM) using solid adaptive rotor flux estimation method. There are outlined the operation performances of the motor during parameter modification. A special observation was made that the performances of the automatic rotative speed adjusting control system with solid adaptive rotor flux estimation depend greatly on the precision of the rotor flux estimation. The behavior of the automatic rotative speed adjusting control system was studied on real time simulations using MATLAB/Simulink environment.**

Keywords: *rotor flux estimation, Gopinath flux-observer, two-phase induction motor, vectorial adjusting control system.*

1. INTRODUCTION

The notable progress made in the last few decades in the domain of machine control and electric drives has it's origin in the refinement of the constructive principles of the servomotor.

The two-phase asynchronous servomotor (TPAS) has been successfully used in controlled electric drive of low and sometimes medium power, being a serious competitor for the direct current motor. This way the TPAS model becomes analogous with the direct current motor for the case in which it is represented in an axis system permanently oriented after the stator, rotor or air gap flux direction.

The mostly utilized orientation method is using the rotor flux, because the adjusting measurements can be determined using PI type regulators. But for induction motors with short-circuit rotors the rotor flux components are not accessible. A more recently solution is represented by the estimation of rotor flux space phaser using adaptive methods based on the two-phase components of stator current and voltage and on rotor speed. Thus, based on the rotor field oriented principle it can be determined the flux and electromagnetic torque control measurements for the induction motor.

2. MATHEMATICAL MODEL

In this paper it is presented the simulation of a vectorial adjusting control system for a two-phase induction motor (TPIM) using solid adaptive rotor flux estimation method. Based on this principle the control measurements for separate control of TPIM flux and electromagnetic torque can be determined. The structure of a system based on adaptive estimation of rotor flux is presented in Figure. 1. The implementation of the such a system was done using MATLAB/Simulink environment.

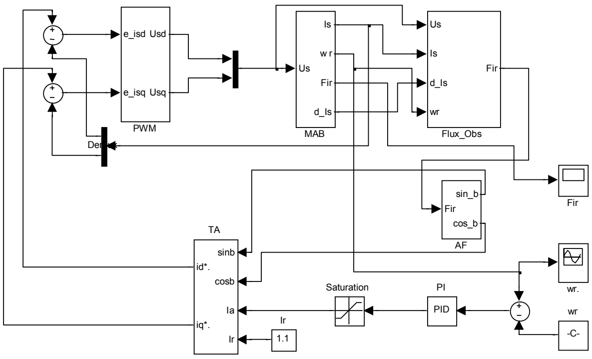


Figure 1. The structure for a TPIM vectorial adjusting control system using adaptive methods for rotor flux estimation

Mathematical model of the two-phase induction motor was formulated using a matrix state equation [3] because this one lends itself to implementations and simulations using software packages like MATLAB/SIMULINK.

$$\begin{bmatrix} \dot{i}_s \\ \dot{\Psi}_s \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \cdot \begin{bmatrix} i_s \\ \Psi_s \end{bmatrix} + \begin{bmatrix} b_1 \\ 0 \end{bmatrix} \cdot [u_s] \qquad (1)$$

where:

$$a_{11} = -\frac{R_s}{\sigma L_s} - \frac{R_r(1-\sigma)}{\sigma L_r}, a_{12} = \frac{L_m}{\sigma L_s L_r}\left(\frac{R_r}{L_r} - j\omega_r\right),$$

$$a_{21} = \frac{L_m R_r}{L_r},\ a_{22} = -\frac{R_r}{L_r} + j\omega_r, \qquad (2)$$

$$b_1 = \frac{1}{\sigma L_s} \tag{3}$$

$$\sigma = 1 - \left(\frac{L_m^2}{L_s L_r} \right), \begin{bmatrix} \dot{i}_s \\ \dot{\Psi}_s \end{bmatrix} = \begin{bmatrix} \frac{di_s}{dt} \\ \frac{d\Psi_s}{dt} \end{bmatrix}$$

From the multiple observer types, in this paper it was chosen the observer with the simulator based on current model and compensation of the estimated measurement based on stator equations. As correcting condition it was chosen the stator current derivative. This estimator is also called reduced order Gopinath observer and has the following structure,

$$\dot{\hat{\Psi}}_r = a_{21} i_s + a_{22} \hat{\Psi}_r + g\left[\dot{i}_s - \left(a_{11} i_s + a_{12} \hat{\Psi}_r + b_1 u_s\right)\right] \tag{4}$$

where, $g = g_a + jg_b$ is gate, the main element which determine the stability of the flux observers as well as the sensitivity to the motor parameters variation and

$$g_a = \left(\frac{\frac{R_r}{L_r}\alpha + \omega_r \beta}{\left(\frac{R_r}{L_r}\right)^2 + \omega_r^2} - 1 \right) \frac{\sigma L_s L_r}{L_m}, \tag{5}$$

$$g_b = \frac{\omega_r \alpha - \frac{R_r}{L_r}\beta}{\left(\frac{R_r}{L_r}\right)^2 + \omega_r^2} \frac{\sigma L_s L_r}{L_m},$$

the gate coefficients and

$$\beta = 0\,, \alpha = K\sqrt{\left(\frac{R_r}{L_r}\right)^2 + \omega_r^2} \tag{6}$$

determine the optimum position of the poles on the negative real axis

The measured correction conditions are the two-phase components of stator voltage and current and the rotor speed. They are applied as input for the solid adaptive flux observer (Flux_Obs). The flux analyzer (AF) computes the modulus and immediate position for the rotor flux spatial phaser and based on that the field orientation is done.

$$\Psi_r = \sqrt{\Psi_{rd} + \Psi_{rq}} \tag{7}$$

$$\sin\beta = \frac{\Psi_{rq}}{\Psi_r}\,, \ \cos\beta = \frac{\Psi_{rd}}{\Psi_r} \tag{8}$$

The axis transformer (TA) realize the rotation with β angle of the active I_A and reactive I_R , components and deliver as output the control signal for PWM.

$$i_{sd}^* = I_R \cos\beta - I_A \sin\beta\,, i_{sq}^* = I_R \sin\beta + I_A \cos\beta \tag{9}$$

It was preferred to keep as control signal for the execution element the stator current because the computation volume is significant lower and it can be avoided the errors due to estimation or variation of stator circuit parameters.

First it was simulated the transient regime for no load start of TPIM in the first 0,05s and after that a resistive torque $T_{rez} = 0{,}03Nm$ was applied. For the rotative speed control system it was used a prescribed nominal value of 157,07 rad/s. The simulations were realized on a TPIM having as input parameters the values in Table 1 and

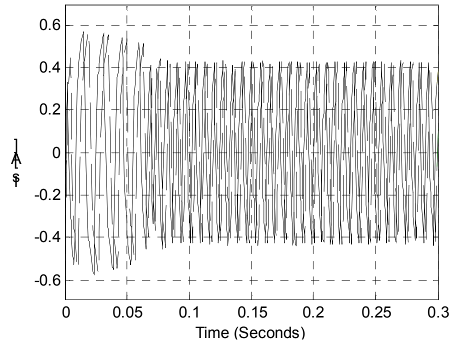
$$P_n = 35W, Z_S = 16, Z_R = 17, n_n = 1500 rot/\min.$$

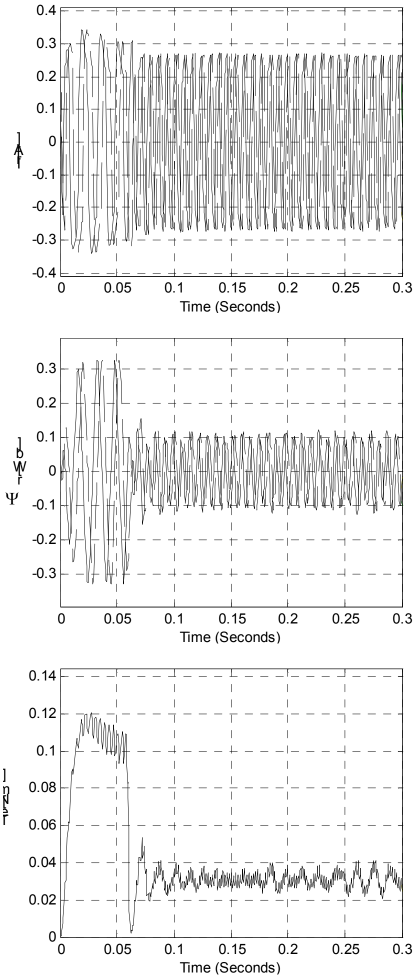
Parameter	Value
P	2
J	3,3x10^{-5} [kgm^2]
Rs	415[Ω]
R	252,33[Ω]
Ls	1,841[Ω]
L	1,538[Ω]
Lm	1,161[Ω]
K	0,1

Table 1. Motor's parameters

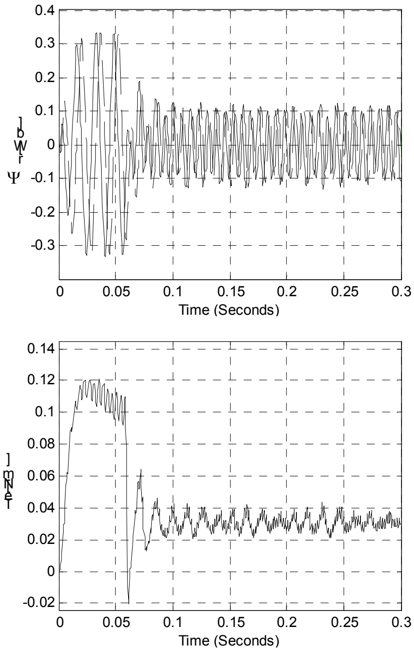
Also the simulations were done for different values of rotor resistance, R_R, Figure. 2. This way we can se one of the essential qualities of the reduce order adaptive flux observer which is the solidity to the rotor resistance variation, influenced by the value of K factor, [1].

a) $R_R = 500\Omega$





b) $R_R = 252,33\Omega$



c) $R_R = 126\Omega$

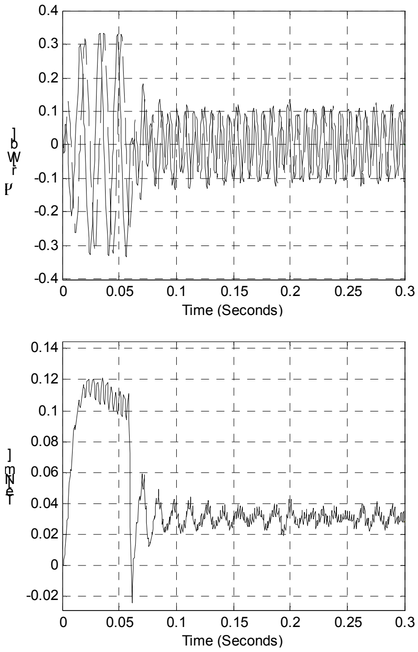
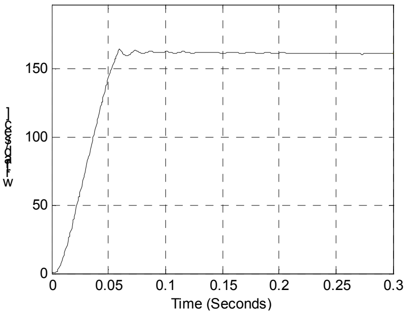


Figure 2. Working characteristic for different R_r values

Imposing different prescribed values for nominal rotative speed: a) $\omega_r = 157,07 rad/\sec$; b) $\omega_r = 120 rad/\sec$; c) $\omega_r = 50 rad/\sec$; d) $\omega_r = 10 rad/\sec$, we can see that the system has stabilized at the imposed value, but this remark is valid only for values near the nominal rotative speed, Figure 3.



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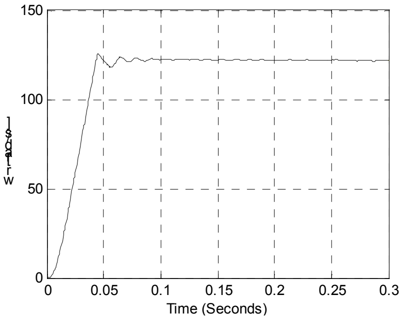

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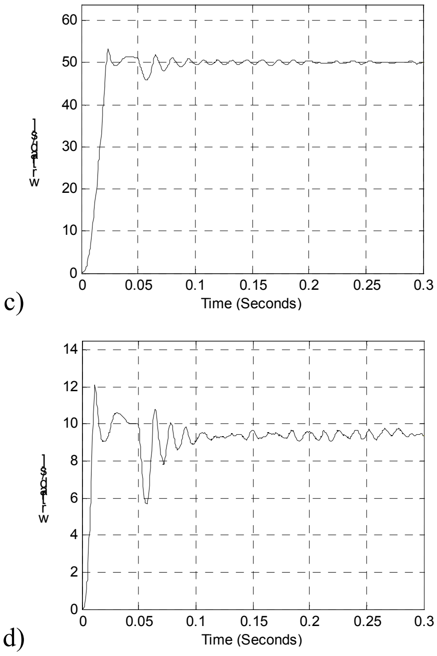

Figure 3. Simulation results for different ω_r values

When the rotative speed value drops and the resistive torque remains steady the stability of the system is lesser. In all the simulations, the characteristics parameters of the automated regulator were kept to the same values, $K_R = 0{,}6; T_i = 0{,}75$. These values ensure best performances for the automated system. The change of these parameters can influence the quality of the characteristic factor, but this is not the subject for the present paper.

3. CONCLUSIONS

Based on the realized simulations a special observation was made that the performances of the automatic rotative speed adjusting control system with solid adaptive rotor flux estimation depend greatly on the precision of the rotor flux estimation

Using the MATLAB/Simulink simulation results and graphics another it can be seen that the success of designing flux observers is determined by pole assigning. Thereby the coordinates *a* and *b* determine the gate coefficients which adjust the weight of error compensator due to rotor resistance.

The Gopinath flux observer has a remarkable stable behavior to motor parameters variation (rotor resistance), depending exclusive on the K coefficient and make it an an important alternative to Kalman filters in sensorless vectorial adjusting control systems.

For different prescribed values of the nominal rotative speed it can be seen that the system stabilized to the imposed value, but only for value near the nominal rotative speeed value. When the rotative speed drops and the resistive torque remains unchanged, the stability of the system is lower.

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