STATE OBSERVER FOR FIELD ORIENTED CONTROL IN HIGH SPEED RANGE FOR EMBEDDED SYSTEMS

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1. INTRODUCTION

This study has been performed on a rotor flux oriented control system with a given induction motor, shown in Fig.1.

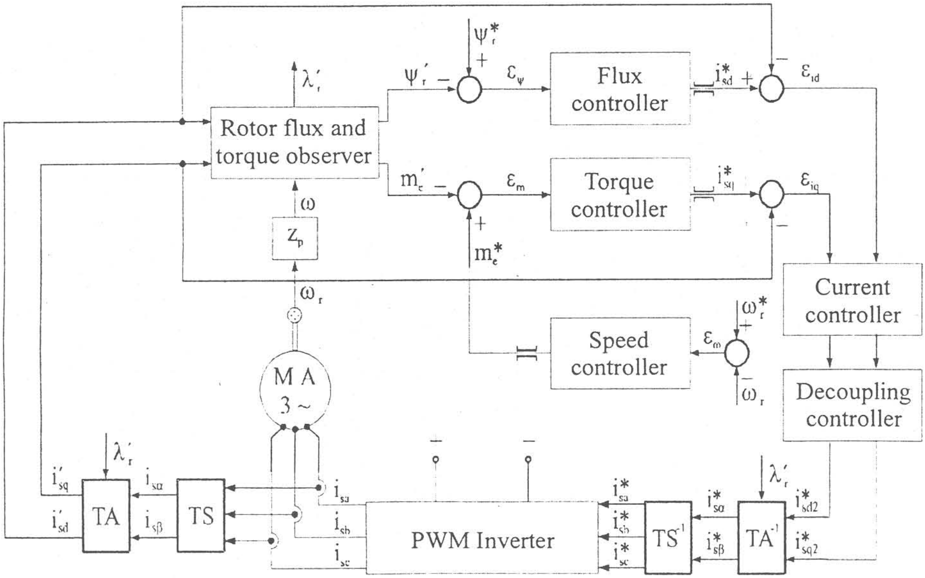

Fig. 1. The rotor flux oriented induction motor drive

2. THE OBSERVER FOR HIGH SPEED RANGE

This observer, which the base structure is simulated in SIMFRAME [3] and presented in Fig. 2, uses the stator voltages and currents measured values as inputs.

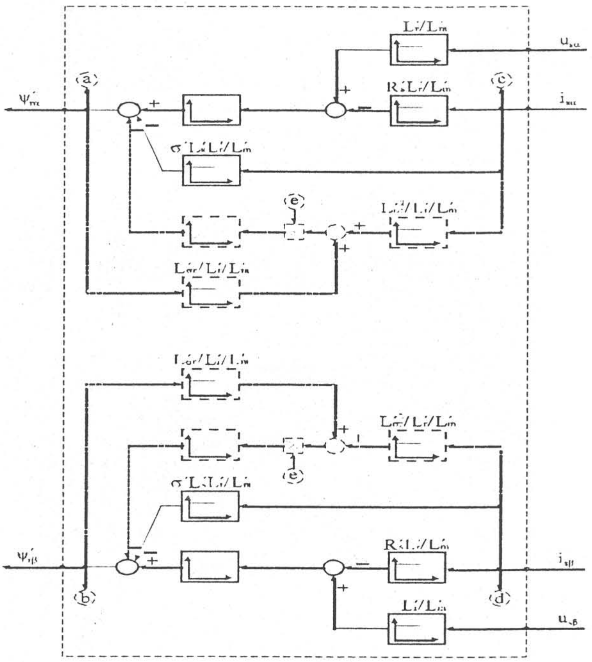

Fig. 2. Simulated observer for high speed range

For the flux and torque estimation new model, will be considered the influence of the main flux paths magnetic saturation.
The L_m inductance was considered as variable parameter and thus, the expressions of the flux derivatives required in the estimation model can be determinate as follows:

$$\Psi_{r\alpha} = \int \frac{L'_r}{L'_m}(u_{s\alpha} - R'_s i_{s\alpha}) \cdot dt - \frac{\sigma L'_s L'_r}{L'_m} i_{s\alpha} - \int \frac{L'_{\sigma r}}{L'_r L'_m}(L'_{\sigma r} i_{s\alpha} + \Psi'_{r\alpha})\left(\frac{dL'_m}{dt}\right) \cdot dt \tag{1}$$

$$\Psi'_{r\beta} = \int \frac{L'_r}{L'_m}(u_{s\beta} - R'_s i_{s\beta}) \cdot dt - \frac{\sigma L'_s L'_r}{L'_m} i_{s\beta} - \int \frac{L'_{\sigma r}}{L'_r L'_m}(L'_{\sigma r} i_{s\beta} + \Psi'_{r\beta})\left(\frac{dL'_m}{dt}\right) \cdot dt \tag{2}$$

The calculation of the derivative $\frac{dL'_m}{dt}$ is made as shown in Fig. 3 using inverse magnetization curve.

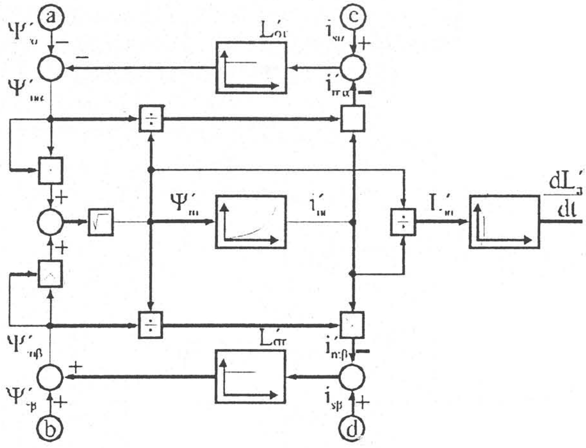

Fig. 3. Calculation of the derivative $\frac{dL'_m}{dt}$

At the observer output the amplitude Ψ'_r and the angular position λ'_r of the orientation flux phasor shall be calculated with the below relations:

$$\Psi'_r = \sqrt{\Psi'^2_{r\alpha} + \Psi'^2_{r\beta}}, \quad \lambda'_r = arctg\frac{\Psi'_{r\beta}}{\Psi'_{r\alpha}}, \qquad (3\ a,\ b)$$

For the torque value estimation in equation (5) is necessary the current torque component calculation by transforming the reference frames:

$$i'_{sq} = -i_{s\alpha}\sin\lambda'_r + i_{s\beta}\cos\lambda'_r, \qquad (4)$$

$$m'_e = \frac{3}{2} z_p \frac{L'_m}{L'_r} i'_{sq}\Psi'_r, \qquad (5)$$

The flux and torque simulation results, performed with the observer presented in Fig. 2 and adapted to the magnetic saturation on the basis of the equations (1), (2) and Fig. 3 are shown in Fig. 4.

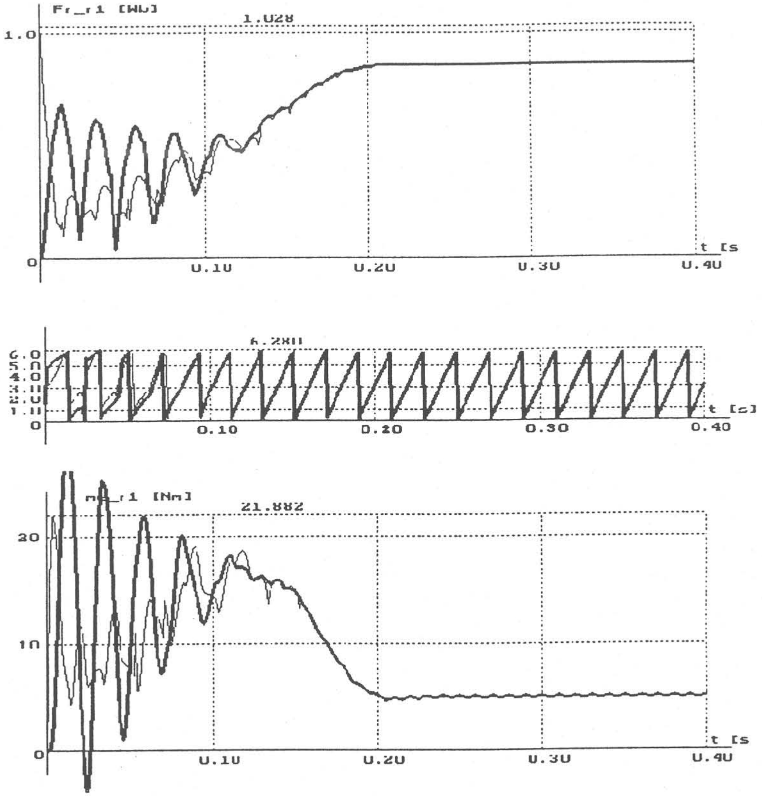

Fig. 4 The estimated amplitude Ψ_r' (a), the angular position λ_r' of the rotor flux (b) and estimated torque m_e' (c), for the observer at high speed range.

The simulation in Fig. 4 refers to the motor, with the data in Appendix, for a starting process with a load torque m_L=5 Nm. It should be noted that this observer model cannot be applied to the speed range nearest to zero where estimation errors are very high. In exchange it behaves better in respect to the inductances variations, which is an advantage when it is used in the speed control systems by field weakening.

3. THE STUDY OF THE OBSERVER SENSITIVITY

Assuming that the input quantities of the observer are correctly measured, without errors, in practice the following issues remains of outmost importance: the errors caused by the slow variations of the stator and rotor resistances, due to the fluctuation of the temperature, as well as the errors caused by the fast variations of the L_m , $L_{\sigma s}$

and $L_{\sigma r}$ inductances, due to the magnetic circuits saturation of the Ψ_m, $\Psi_{\sigma s}$, $\Psi_{\sigma r}$ fluxes.

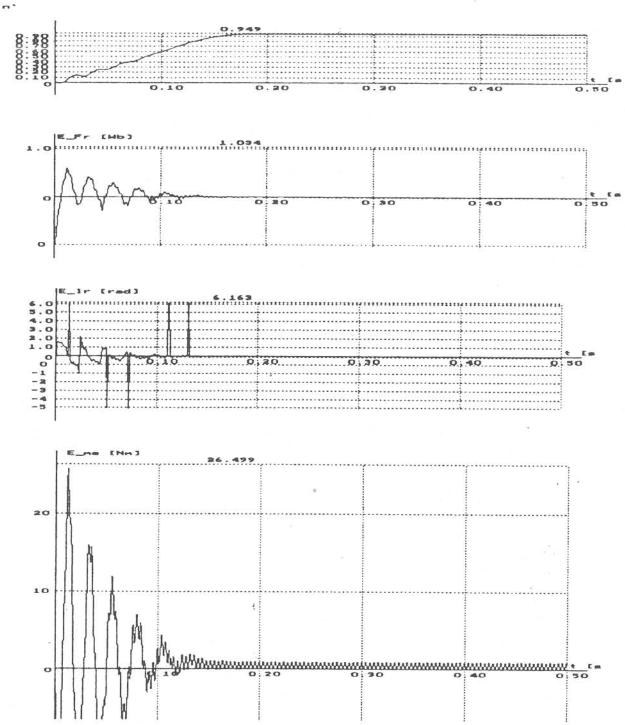

Fig. 5. The $\Delta\Psi_r$, $\Delta\lambda_r$ amplitude and phase errors of the rotor flux and Δm_e in case of the observer at high speed range in Fig.2., at incorrect adjustement of the L'_m, $L'_{\sigma s}$, $L'_{\sigma r}$ inductances with $\pm 10\%$

In the case of the rotor flux estimation, the amplitude error and the phase error shall be used according to:

$$\Delta\Psi_r = \Psi_r - \Psi'_r;\ \ \Delta\lambda_r = \lambda_r - \lambda'_r \qquad (6)$$

At the torque estimation the following error quantity shall be used:

$$\Delta m_e = m_e - m'_e \qquad (7)$$

The simulation results of the above defined error quantities are given in Fig.5 for the observer behavior. The simulations were made for the starting process of the motor given in the Appendix, with a load torque $m_L = 5$ Nm, considering different cases of the incorrect adjustment of the observers parameters. Further the results of this study shall be presented. The diagram of the observer at high speed range is influenced by the stator resistance $R_s^{'}$ and the $L_s^{'}$, $L_r^{'}$ inductances. The results of simulations presented in Fig.5 show that an incorrect adjustment, one way or another, of the inductances parameters causes the same error quantities namely: zero values for the stationary errors $\Delta\Psi_r$, $\Delta\lambda_r$ and the torque is underestimated with an error of Δm_e .At low speeds in a dynamic regime, the estimation errors of the rotor flux and torque, reach high values.

4. CONCLUSIONS

The observer having as inputs the measured values of the stator voltages and currents, has fully eliminated the influence of the rotor resistance variation, this being its main advantage. As shown in the present study the simple structure of this estimator can be used in appropriate conditions even when incorrectly adjusting $R_s^{'}$, $L_s^{'}$, $L_r^{'}$ parameters which influence its behavior. However, the issue of the influence of the stator resistance variations, due to temperature, still remains.The proposed adaptation to magnetic saturation, of this type of observer leads to increase of his performances. Consequently, this new model has a better behavior at the inductances variations, which recommends it for the use in the feedback loops of the speed control systems by field weakening. But this observer is not appropriate in the behavior of low speed range towards zero where it should be replaced by second type of observer having as inputs the measured values of the stator voltages and rotor angular velocity.

5. REFERENCES

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[3] Ungar, R.: Simulation research of systems used in automatic measurement, identification and control – Doctoral thesis, "Transilvania" University of Brasov, 1997

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6. APPENDIX

The induction motor data:

$P_N = 1.1$ kW; $z_p = 2$; $m_{eN} = 5$ Nm;

$n_0 = 1500$ rot/min; $J = 0.0106$ kg m^2;

$R_s = 7.78\ \Omega$; $R_r = 7.10\ \Omega$;

$L_{\sigma s} = 0.037$ H; $L_{\sigma r} = 0.02$ H; $L_m = 0.45$ H.