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ANALYSIS OF ELECTROMECHANICAL CONVERTER – DELPHI IMPLEMENTATION (PART II)

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Abstract: The paper deals with the problem of numerical simulations of electrical machines. The results of numerical analysis have been presented and discussed widely. The Delphi programming based has been widely used.
Keywords: Delphi programming, electromechanical converter, saturation.

1 Differential equations set

For the electromechanical converter considered in the Part I the six voltage equations result from Kirchhoff's law

$$u_k(t) = R_k i_k + L_{\sigma k}\frac{di_k}{dt} + L_\mu(i_{\mu k})\frac{di_{\mu k}}{dt}. \tag{8}$$

Thus, two difference equations are for stator phases in the form of

$$u_A(t) - u_B(t) = R_A i_A(t) - R_B i_B(t) + \frac{d\Psi_A}{dt} - \frac{d\Psi_B}{dt}, \ldots \tag{8a}$$

and four for rotor circuits in the form

$$0 = R_a i_a(t) - R_b i_b(t) + \frac{d\Psi_a}{dt} - \frac{d\Psi_b}{dt}, \ldots \tag{8b}$$

The time –derivative of magnetic flux coupled with e.g. phase A equals to

$$\frac{d\Psi_A}{dt} = L_{\sigma A} i_A + \frac{d\Psi_A}{di_{\mu A}}\left\{\frac{3}{2}\frac{di_A}{dt}\right\} +$$

$$+\frac{d\Psi_A}{di_{\mu A}}\left\{\left(\frac{di_{a1}}{dt} + \frac{di_{a2}}{dt}\right)s(\varphi + \tfrac{\pi}{3}) + \omega(i_{a1} + i_{a2})c(\varphi + \tfrac{\pi}{3})\right\} + . \tag{8c}$$

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where it was denoted

$$L_{\mu k} = \frac{d\Psi_k}{di_{\mu k}}, \qquad \omega = \frac{d\varphi}{dt} = p\omega_m = p\frac{d\varphi_m}{dt}. \tag{9a,b}$$

The state equations (8a,b,c) together with mechanical state equation create the electromechanical converter state equations which is implemented on the Delphi platform and solved subsequently. The torque can be evaluated by means of coenergy function [4,6]:

$$T_e = \frac{\partial W_c}{\partial \varphi_m}, \quad \text{where} \quad W_c = \sum_{k=1}^{M} \int_0^{\Psi_k} i_k d\Psi_k \tag{10, 11}$$

Hence, the electromagnetic torque is equal to

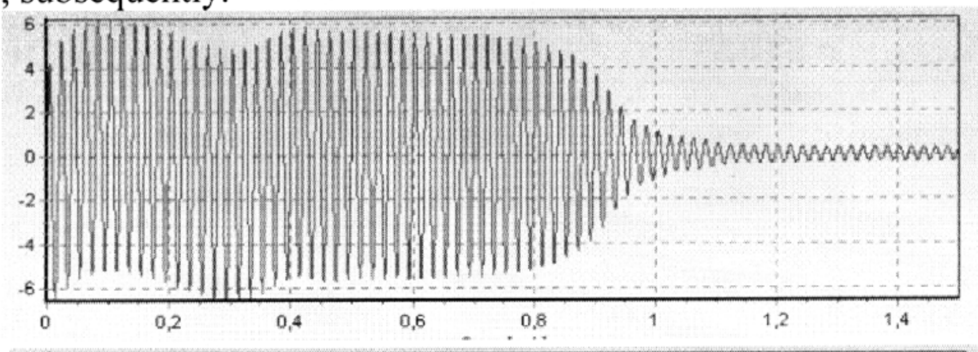
$$T_e = \sum_{k=1}^{M} i_k \frac{\partial \Psi_k}{\partial \varphi}. \tag{12}$$

The above written equation enables to calculate the electromagnetic torque developed by electromechanical converter.

2 Numerical implementation

There was composed numerical program on Delphi platform. This program enables to present the numerical solution of difference equation set described in previous Part I. The few typical states of work for the induction motor chosen have been considered. The start-up curves have been presented for the motor chosen (U_n=6 [kV], P_n=450 [kW], I_n=51 [A], n_n=1458 [rpm], T_n=2958 [Nm], T=1000 [Nm]). For this induction motor the current for phase A for the start-up state of work presents Figs 4a,b and the time harmonics are shown in Figs 5a,b., subsequently.

a)



b)

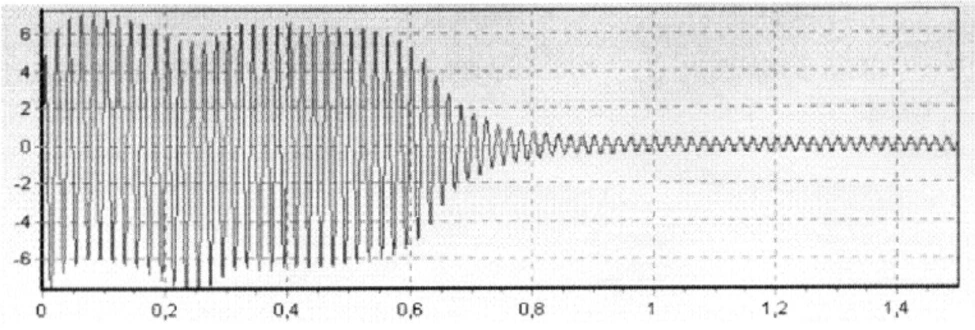
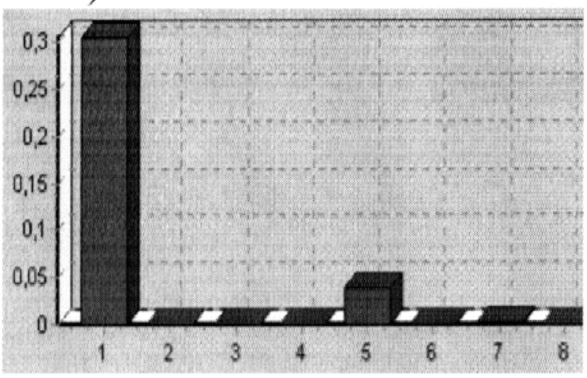


Fig.4. Relative current versus time [s] for nominal voltage supply $U=U_N$ (a) and for voltage $1.2U_N$ (b) at the same load torque

a)



b)

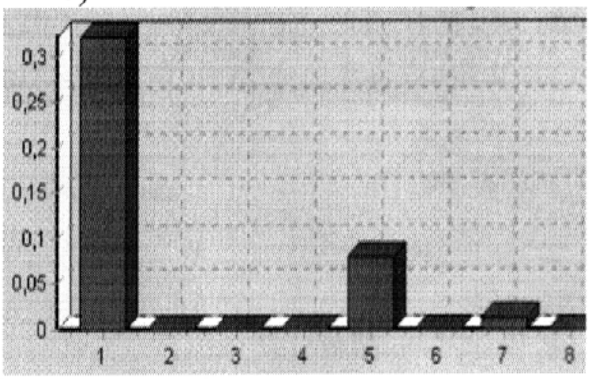
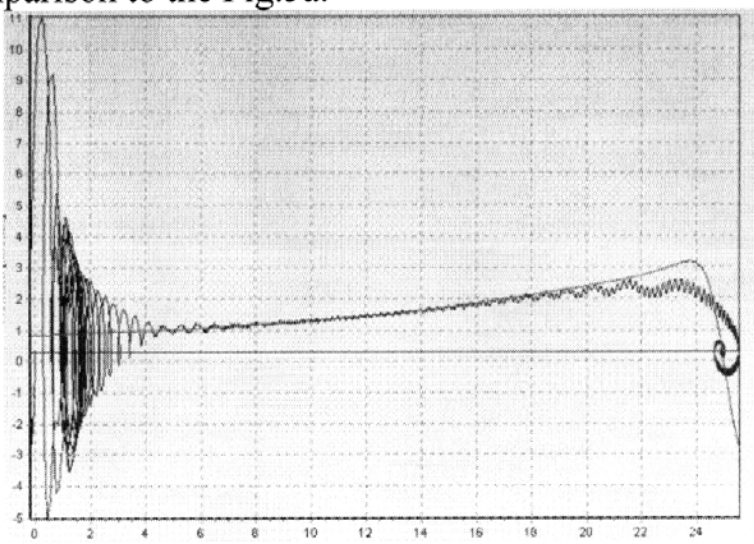
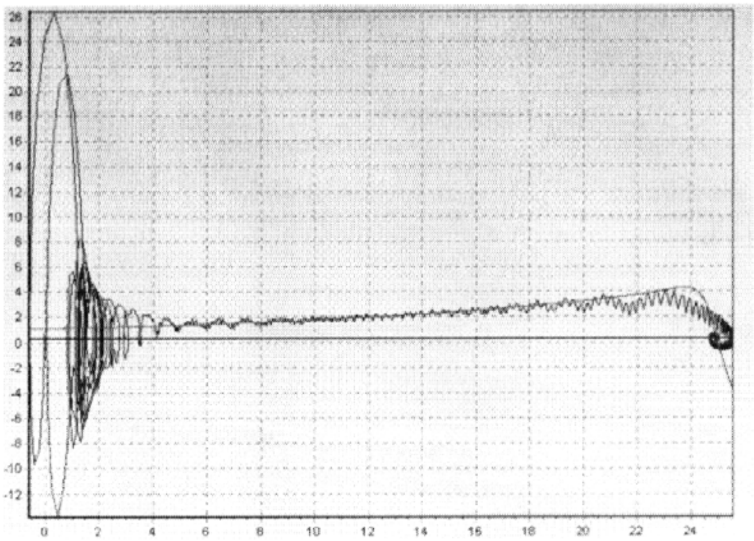


Fig.5. Relative current harmonics for nominal voltage supply $U=U_N$ (a) and for voltage $1.2U_N$ (b) at the same load torque

It can be seen that in the Fig. 5b appears the fifth and seventh time-harmonics in comparison to the Fig.5a.



a)



b)

Fig.6. Relative electromagnetic torque versus speed [rps] for nominal voltage supply $U=U_N$ (a) and for voltage $1.2U_N$ (b) at the same load torque

The increase of electromagnetic torque is seen in Fig.6b in comparison to Fig.6a at the same load torque (the smooth line is the steady-state curve).

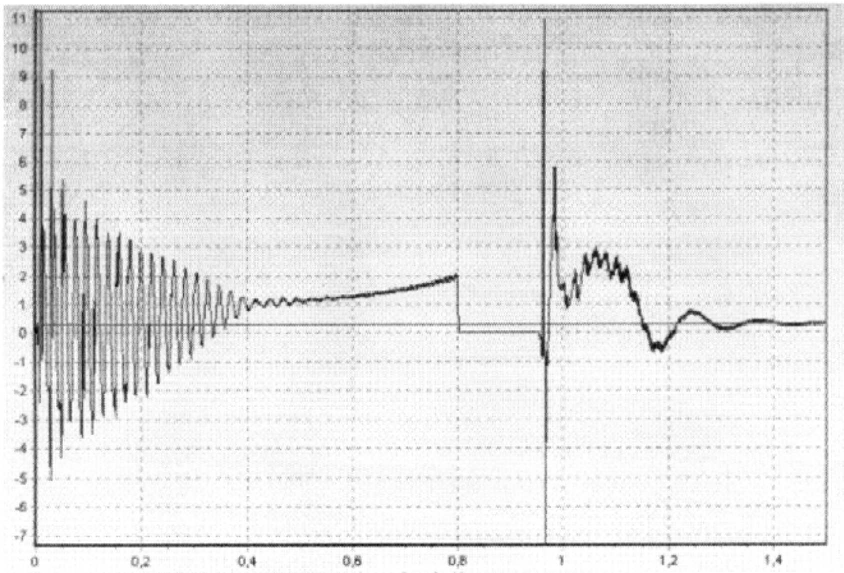


Fig.7. Relative torque T_e/T_n versus time [s] for nominal voltage supply

The Fig.7 presents the electromagnetic torque for motor start (0÷0.8 [s]), supply break (0.8÷0.96 [s]) and restart (0.96÷1.5 [s]).

3 Conclusions

The presented method enables to simulate the work of electromechanical converter taking into account the saturation of magnetic circuit.

The DELPHI object programming improves the simulations base for technical and educational purposes.

The elaborated program in a very simply way shows the influence of saturation on work of electromechanical converter.

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