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INFLUENCE OF PARAMETERS ON ELECTROMECHNICAL TRANSIENTS OF ELECTRICAL DRIVES WITH ELASTIC ELEMENTS

Dr. Sc. Nysret Avdiu
Faculty of Electrical and Computing Engineering
Prishtina, Kosova

Dr. Sc. Shaban A. Buza
Faculty of Mechanical Engineering
Prishtina, Kosova

ABSTRACT
This paper deals with the problem of influence of construction parameters on electromechanical dynamic processes of electric drives with induction motor when mechanical system is treated as elastic. The paper comprised of the analytical modelling of electrical motor and mechanical system. On base of the derived mode the parametric investigation on currents, moments and oscillation on torsion have been done. The Mat-Lab program package is developed for simulation.
Keywords: Dynamics of the electrical drives, induction motor, elastic mechanical system

1. INTRODUCTION
During last couple of decades, the electrical drive systems had met an epochal innovation. Thanks to the progress in power electronics and advanced control technologies the rolling stock drive motor system has changed from DC motor system to the three-phase induction motor system, employing digital controlled variable-voltage variable-frequency (VVVF) inverter.
Contemporary working environment of high power machines and electromechanical devices sets constantly rising requirements on their dynamic properties. Complex operating tasks have to be carried out and the required working tool trajectories have to be maintained under dynamically variable loads. The complex structure of the device and dynamic changes of load generate vibrations m the system and, subsequently, noise, which is a nuisance to the operators of the device. Vibrations cause initiation of fracture growth, which leads to failures and destruction of the structure. Under market economy conditions the rate of energy consumption by these systems is also important, and it is influenced not only by the dynamics and the structure of the system, but also by the manner of its control. These elements can be optimised already at the stage of design. These problems can efficiently be analysed only by means of mathematical modelling [1, 2].

2. MODEL OF AN ELECTROMECHANICAL DRIVE SYSTEM
The design and calculation of electric drives very often are based on incomplete knowledge of the interconnections of each element of an electric drive, especially during the dynamic regimes. In electromechanical systems, both the electrical and the mechanical part of the drive are a dynamic system. These parts are intercoupled. It is therefore necessary, when analysing dynamic phenomena, to apply a model that enables electromechanical coupling. In this paper since authors hasn't the data for simulation of complete vector drive system with induction motor is given a general approach of studying of parametric investigation of an electrical drives with induction motor and elastic mechanical system Vector drives, which have been developed and improved in recent years, enable

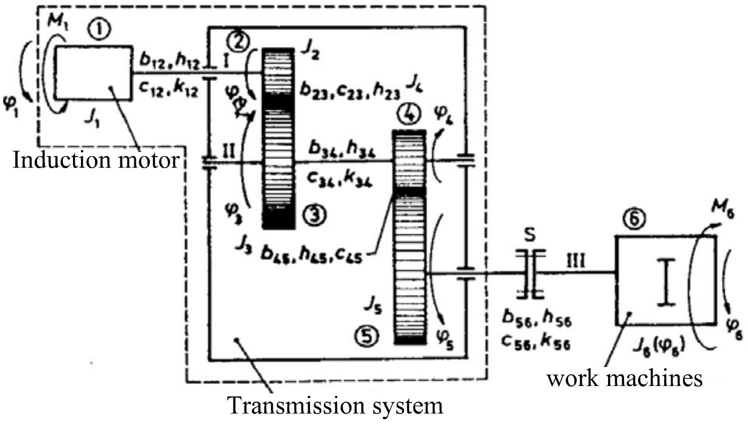


Figure 1.

accurate speed control and full control of the torque of a squirrel-cage motor. The solutions applied vary in the methods of affecting the speed and torque and m the manner of evaluating the internal state of the motor. The most widespread solution is the Field Oriented Control. Separate control of the rotor current, which is responsible for the torque, and of the magnetising current, which generates flux, enables these drives to attain operating parameters comparable to those of direct current drives. The frequency converter can therefore control the speed and the torque independent of each other.

Very often in the industry is applied the solution of the electrical drive with induction motor and transmission system of the relatively low speed piston type mechanism. The high speed of the induction motor is reduced with mechanical system-reductor. The system is showed in *Figure 1*.

The model includes: mathematical modelling of electrical part and mathematical modelling of mechanical system. These two models and connected to each other with angular velocity of rotor of electrical machines. Thus, we have two very accurate models to describe both electro-magnetic and the mechanical properties of the whole systems.

A clear and comprehensive description of the dynamic behavior of induction motor is a fundamental requirement for their application in drive system [1,2,3,4,5]:

$$\frac{d\psi_{sd}}{d\tau}=u_{ds}-\frac{r_s}{\sigma l_s}\psi_{ds}+\omega_k\psi_{qs}+\frac{r_s\cdot l_m}{\sigma l_s l_r}\psi_{dr},\qquad \frac{d\psi_{qs}}{dt}=u_{qs}-\frac{r_s}{\sigma l_s}\psi_{q_s}-\omega_k\psi_{ds}+\frac{r_s l_m}{\sigma l_s\cdot l_r}\psi_{qr}$$

$$\frac{d\psi_{dr}}{dt}=-\frac{r_r}{\sigma l_r}\psi_{d_r}+(\omega_k-\omega)\psi_{qr}+\frac{r_r l_m}{\sigma l_s l_r}\psi_{ds};\qquad \frac{d\psi_{qr}}{dt}=-\frac{r_r}{\sigma l_r}\psi_{qr}-(\omega_k-\omega)\psi_{ds}+\frac{r_r l_m}{\sigma l_s l_r}\psi_{qs} \tag{1}$$

$$M_{em}=\frac{3}{2}p\frac{l_m}{\sigma l_s l_r}(\psi_{ds}\psi_{qr}-\psi_{qs}\psi_{dr})$$

The dynamic model of mechanical system of electrical drives with AC motor and n-stage transmission systems with piston type of mechanism is based on assumptions given on [2] building the dynamic model of the electrical drive given in *Figure 1.* and represented in *Figure 2.* All angles of rotation of corresponding rotary masses are reduced at the shaft of rotor of electrical machine [3].

The mechanical system will be treated with n-stage coordinates and based on equations of **Lagrange**-it, finally will find a set of differential equations which describe the non-stationary motion of mechanical system in the matrix form:

$$[J^*][\ddot{q}]+[b^*][\dot{q}_1]+[c^*][q_2]=[M^*] \tag{2}$$

Matrix equation (2) together with system of differential equation of induction motor (1) represent the general mathematic model of electric drives system with induction machines set of the piston type pump with n-stage power transmission with elastic members involving the dynamic characteristics of the induction motor and changeability of moment of inertia of the working mechanism. .

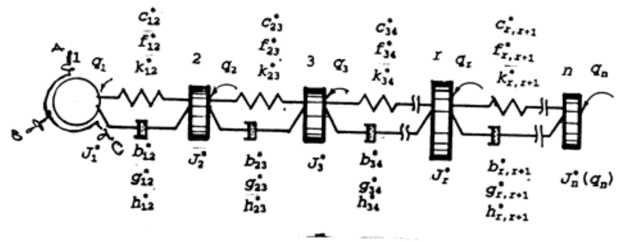


Figure 2.

2. SIMULATION RESULTS

The model discussed above have been applied for electric drive system with induction machines set of the piston type pump with 2-stage power transmission with elastic members

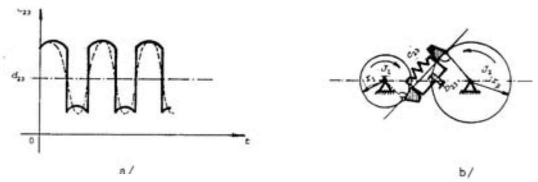


Figure 3.

involving the dynamic characteristics of the induction motor and changeability of moment of inertia of the working mechanism. The stiffness of teeth of gearboxes is showed in the Figure 3. The function describe the stiffness of the teeth pair 2-3, and 4-5:

$$c_{23}(t) = d_{23} + a_{23}\cos(\omega_{23,teeth}\ t),\quad c_{45}(t) = d_{45} + a_{45}\cos(\omega_{45,teeth}\ t) \qquad (3).$$

where is: $\omega_{23teeth}$, $\omega_{45teeth}$ [r/s], frequency of stiffness; a_{23}, a_{45} [Nm/r]- amplitude of changeable part of stiffness; d_{23}, d_{45} [Nm/r] constant part of the stiffness; r_1, r_2, r_3, r_4 [m] radius of the gearbox 1 and 2; 3 and 4, b[m]- width of the gearbox. In the *Figure 3* is showed kinematics scheme of piston type mechanism. Moment of inertia of load mechanism is:

$$J_6 = A + B\,[\sin(\varphi) + \frac{1}{2}\lambda\sin(2\varphi)]^2,\ A = J_m + r^2 m_0\frac{\rho_0}{l}, B = r^2(m_k + m_0\frac{1-\rho_o}{l}), \lambda = \frac{r}{l} \qquad (4)$$

and the load torque:

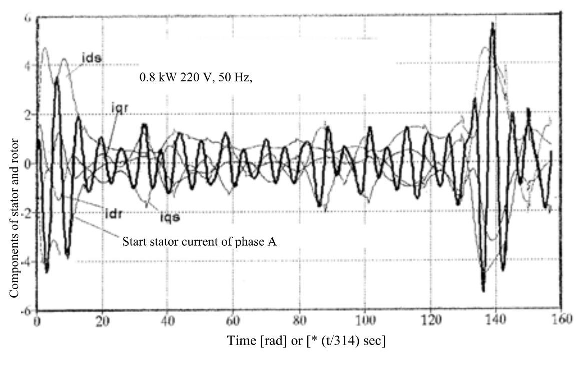
$$M_6 = M_p\cos(\Omega\ t) \qquad (5)$$

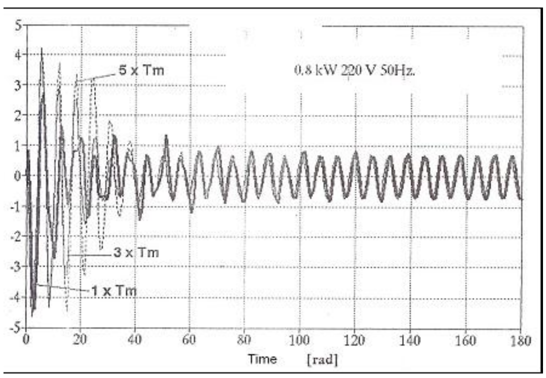
After applying the matrix equation (2) we have:

$$\begin{aligned}
&J_1\ddot{q}_1 - b_{12}(\dot{q}_2-\dot{q}_1) - h_{12}(\dot{q}_2-\dot{q}_1)^3 - c_{12}(q_2-q_1) - k_{12}(q_2-q_1)^3 = M_1\\
&J_2\ddot{q}_2 + b_{12}(\dot{q}_2-\dot{q}_1) + h_{12}(\dot{q}_2-\dot{q}_1)^3 + c_{12}(q_2-q_1) + k_{12}(q_2-q_1)^3 -\\
&-b_{23}(\dot{q}_3-\dot{q}_2) - h_{23}(\dot{q}_3-\dot{q}_2)^3 - [d_{23} + a_{23}\cos(\omega_{23}t)]r_2^2(q_3-q_2) = 0\\
&J_3\ddot{q}_3 + b_{23}(\dot{q}_3-\dot{q}_2) + h_{23}(\dot{q}_3-\dot{q}_2)^3 + [d_{23} + a_{23}\cos(\omega_{23}t)]\,r_2 r_3(q_3-q_2) -\\
&-b_{34}(\dot{q}_4-\dot{q}_3)^3 - h_{34}(\dot{q}_4-q_3)^3 - c_{34}(q_4-q_3) - k_{34}(q_4-q_3)^3 = 0\\
&J_4\ddot{q}_4 + b_{34}(\dot{q}_4-\dot{q}_3) + h_{34}(\dot{q}_4-\dot{q}_3)^3 + c_{34}(q_4-q_3) + k_{34}(q_4-q_3)^3 -\\
&-b_{45}(\dot{q}_5-q_4) - h_{45}(\dot{q}_5-q_4)^3 - [d_{45} + a_{45}\cos(\omega_{45}t)]r_4^2(q_5-q_4) = 0\\
&J_5\ddot{q}_5 + b_{45}(\dot{q}_5-\dot{q}_4) + h_{45}(q_5-q_4)^3 + [d_{45} + a_{45}\cos(\omega_{45}t)]r_4 r_5(q_5-q_4) -\\
&-b_{56}(\dot{q}_6-\dot{q}_5) - h_{56}(\dot{q}_6-\dot{q}_5)^3 - c_{56}(q_6-q_5) - k_{56}(q_6-q_5)^3 = 0\\
&[A_6 + B_6(\sin q_6 + \frac{1}{2}\lambda\sin 2q_6)^2]\ddot{q}_6 + [B_6(\sin q_6 + \frac{1}{2}\lambda\sin 2q_6)(\cos q_6 +\\
&\lambda\cos 2q_6)]\dot{q}_6^2 + b_{56}(q_6-q_5) + h_{56}(q_6-q_5)^3 +\\
&+c_{56}(q_6-q_5) + k_{56}(q_6-q_5)^3 = M_6
\end{aligned} \qquad (6)$$

Differential equations (6) together with set of differentia equation for dynamic regimes of induction motor equations (1-6) describe the transient electromechanical process in the electrical drive with elastic elements. The mechanical parameters are calculated for each mechanical elements of the electrical drive for the data from [2]. The nonlinear differential equation (1) of induction motor and differential equation of mechanical elastic system (2) are connected through speed of rotation of rotor shaft ω_{el}=p≅ω_{mek} and represent the most general dynamic model of electrical drives. The number of differential equation is 17. For solving of the nonlinear differential equation have been used Matlab.

The dynamic parametric investigation was done changing the mechanical constant of the electrical motor. The calculated characteristics are presented in the Fig. 4,5, 6 and 7.





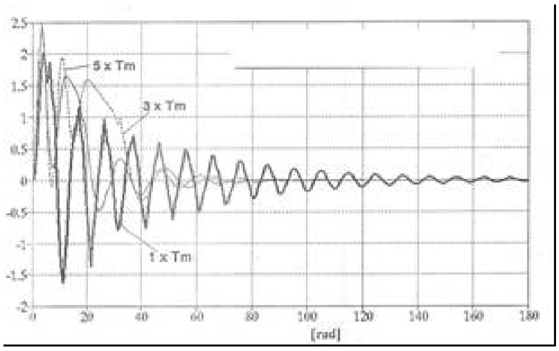


Figure 6. Starting current of induction motor for different mechanical constant T_m

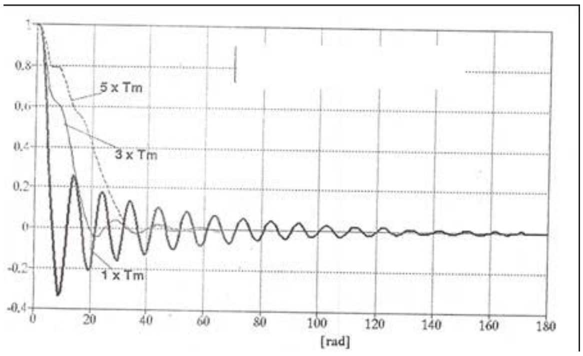


Figure 7. Electromagnetic torque of induction motor for different mechanical constant T_m

4. CONCLUSIONS

On the basis of electromagnetic and mechanical theory is formed an mathematical model of electric drives system with induction machines set of the piston type pump with n-stage power transmission with elastic members involving the dynamic characteristics of the induction motor and changeability of moment of inertia of the working mechanism for investigations of transient electromechanical processes. The derived model is used for calculation of dynamic currents and moments of electrical for different mechanical constant of the induction motor. The computer program package is developed in Matlab.

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