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CONTENTS

Session I. Adaptive and Nonlinear Control

Session II. Control of Electromechanical Systems

Session III. Identification, Signal Processing and Disturbance Compensation

Session IV. Control Applications in Engineering

THE REALIZATION OF THE ALGORITHMS OF PROGRAMMED CONTROL IN THE SYSTEMS OF SOFT START WITH INDUCTION MOTOR

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***Abstract:** An approach is proposed to the formation of induction motor control algorithms in the systems of soft start on the basis of the required trajectory of acceleration by the means of the microprocessor control system.*

INTRODUCTION

At present in the technological processes of the electromechanical conversion of energy two main types of the adjustable automated electric drive (AED) are used – "frequency converter – induction motor" (FC-IM) system and "thyristor voltage regulator – induction motor" (TVR- IM) system. The first form of AED is most promising today, but high costs substantially limit its application. At the same time due to of the high reliability and the satisfactory mass-and-size, cost and regulation properties in recent years substantially was expanded the field of application of AED of the second class thanks to the use of the TVR-IM systems with broken connection on velocity (torque). Such systems called also start-up induction motor systems (SIMS).

The basic task which appears during designing SIMS is to propose algorithm of the formation of the angle of control of thyristors, which would make possible to obtain the required trajectory of a change in the velocity IM during the assigned starting time, and also to exclude self-oscillating processes and modes with the peaking from the dynamics of system [1].

STATEMENT OF A PROBLEM

Traditional approach to the formation of the algorithms of TVR control, which widely used in SIMS of the chief domestic and foreign producers (Triol, Siemens, ABB, Danfoss, Mitsubishi elec. etc) [2-5] consists in control of the voltage by changing the angle of the opening the thyristors, included in pairs antiparallelly in each phase along the previously programmed trajectory. In this case the form of trajectory is chosen according to the load characteristic, determined by the field of application and by special features of AED (mechanical characteristic, etc.). The possible trajectories of the TVR-IM voltage formation are represented in figure 1.

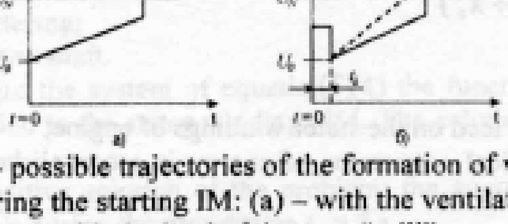

Figure 1 – possible trajectories of the formation of voltage on the input TVR during the starting IM: (a) – with the ventilator load; (b) – with the load of the type "mill".

In the paper [1] is shown that the linear formation of voltage trajectory on the TVR input does not consider it number of the substantially nonlinear special features of TVR-IM system with pulse-phase control. Therefore in the system can appear the self-vibrating modes, the modes with the peaking, which lead to the current splashes in the chain of stator and the strong moment oscillations on the shaft of engine.

The **purpose** of this work consists in proposing of possible algorithm of the formation of voltage on the TVR input, considering nonlinear nature of IM.

THE ALGORITHM OF THE TVR-IM PROGRAMMED CONTROL

The process of development of the algorithms of programmed control is connected with the need for the analysis of the special features of both the unit of control and the system in whole. This analysis can be carried out with the use of a mathematical model in the one of the systems of computer mathematics. For the solution of given problem it was most convenient to use the "MathCAD 8.0"® (MathSoft, inc.) system, because its interface makes possible to clearly and rapidly obtain the required results in the customary form with the satisfactory precision.

The proposed algorithm of programmed control consists of the following.

1. Let are known the reference parameters of equivalent circuit of IM: the effective resistance of stator winding R_1, the effective resistance of rotor winding R_2, inductive short-circuit impedance x_k, synchronous frequency of the rotation of the rotor ω_0, the moment of the inertia of the engine J with the led to the rotor shaft load moment, the nominal torque of the engine M_{nom} (R_1=0.067 ohm, R_2=0.032 ohm, x_k=0.534 ohm, ω_0=157 rad/s, J=1.242 kg* m^2, M_{nom}=356 N*m for IM 4A225M4У3 [6]). Run-up time is given t_p = 5 s.
2. It is necessary to obtain the dependence of the voltage, supplied to the stator windings of engine, from the time, which, for example, will make it possible to provide the linear increase of the angular velocity of rotation of rotor during the prescribed run-up time (Fig. 2)

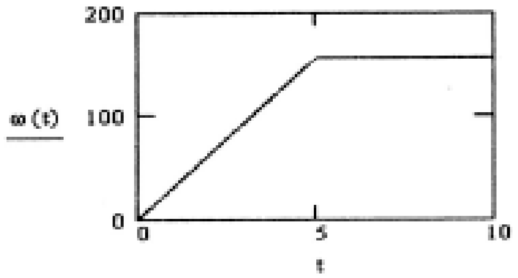

Figure 2. Diagram of the required on the condition dependence of frequency on the time.

3. It is known that electromagnetic torque of the generalized machine in the steady-state mode is equal [7]:

$$M_э = \frac{3U^2 R_2}{\omega_0 s((R_1 + R_2 / s)^2 + x_k^2)}, \qquad (1)$$

where s – the slip

$$s = (\omega_0 - \omega)/\omega_0, \qquad (2)$$

U – the effective voltage of feed on the stator windings of engine;

The electromechanical conversion of energy is accomplished according to the following equation:

$$M_э - M_C = J\frac{d\omega}{dt}, \qquad (3)$$

where M_C – moment of resistance (for the ventilator load let us take M_C=0.017ω^2).

4. It is possible now to obtain the dependence of voltage from the time (Fig. 3) during the uniform starting with the assigned run-up time, by substituting equations (1), (2) in (3) and, having the required dependence of velocity and acceleration on the time.

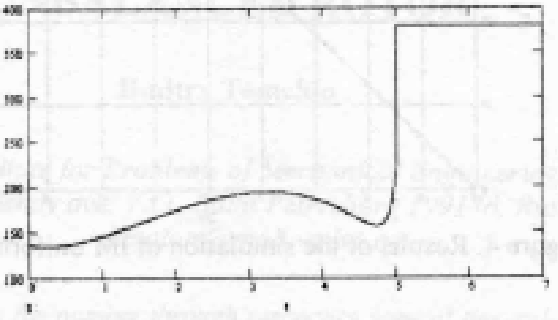

Figure 3. Graph of the effective voltage, supplied to the stator windings IM.

The behavior of engine with the feed by voltage, which is changed according to the obtained dependence (Fig. 3), it is possible to investigate by using the well-known [8] mathematical model IM with the short-circuited rotor, recorded relative to flux-linkage in the coordinate system ($\alpha - \beta$), which is rigidly connected with the stator. This model is the system of ordinary differential equations of the 5th order with the periodic coefficients:

$$\begin{cases} \dfrac{d\psi_{s\alpha}}{dt} = u_{s\alpha}(t) - \alpha_s\psi_{s\alpha} + k_r\alpha_s\psi_{r\alpha}; \\ \dfrac{d\psi_{s\beta}}{dt} = u_{s\beta}(t) - \alpha_s\psi_{s\beta} + k_r\alpha_s\psi_{r\beta}; \\ \dfrac{d\psi_{r\alpha}}{dt} = -\alpha_r\psi_{r\alpha} + k_s\alpha_r\psi_{s\alpha} - p_{П}\omega_r\psi_{r\beta}; \\ \dfrac{d\psi_{r\beta}}{dt} = -\alpha_r\psi_{r\beta} + k_s\alpha_r\psi_{s\beta} + p_{П}\omega_r\psi_{r\alpha}; \\ \dfrac{d\omega_r}{dt} = \dfrac{1}{J}\left[\dfrac{3}{2}p_{П}\dfrac{k_r}{\sigma L_s}(\psi_{s\beta}\psi_{r\alpha} - \psi_{s\alpha}\psi_{r\beta}) - M_c\right] \end{cases} \qquad (4)$$

where, $\psi_{s\alpha}(\psi_{r\alpha}), \psi_{s\beta}(\psi_{r\beta})$ – the projection of the vector of the flux-linkage of stator (rotor) on the the axis of the coordinate system α–β;

$\alpha_s(\alpha_r), k_s(k_r)$ – the factors of attenuation and connection of stator (rotor).

$p_{П}$ – the number of pairs of poles of the engine:

$u_{s\alpha}(t),\ u_{s\beta}(t)$ – the two-phase voltage, applied to the stator. It is obtained by means of the Clark direct transformation from the three-phase [6, 8] voltage of the power source;

ω_r – the angular velocity of rotation of the rotor;

J – the moment of the inertia of electric drive, led to the shaft of the engine:

L_s – the inductance of stator;

σ – coefficient of scattering;

M_c – static torque on the shaft.

Now we can substitute into the system of equations (4) the function of the effective value of voltage obtained above, applied to the stator windings IM. The solution of the system is shown on Figure 4.

Figure 4 demonstrates positive solution of the problem: the angular velocity of rotor linearly grows from 0 to w_0 = 157 rad/s during the preset time t_p = 5 s.

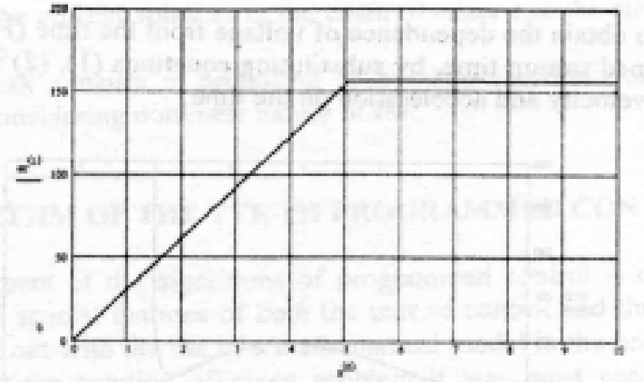

Figure 4. Results of the simulation of IM uniform starting.

CONCLUSION

The contemporary systems for microprocessor control make it possible to design in the real time the state of the object of control for the selection and realization of the algorithm of the control most optimum for one criterion or another.

On the basis of the solution of the differential equation of the electromechanical conversion of energy (2) in the work was obtained the dependence of stator voltage from the time, which makes it possible to carry out starting of IM according to the predetermined trajectory during the preset time. The adequacy of the obtained results was checked with the use of the IM precise model, recorded relative to the flux-linkage of the windings of engine.

Further development of the ideas, presented in the article, can pass through the realization of the obtained algorithm in the microprocessor system of control. Fundamental problem will consist in the search for the most optimum method of the idea of the obtained dependence U(t) (Fig. 3), from the point of view of the expenditures of processor time. It is possible to go by means of the numerical integration of equation (2) or by proposing one version or another of approximation.

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