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Control system asynchronous electric traction drive

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Abstract
The analysis of solutions of problem of rational use of the asynchronous engine parameters as a part of asynchronous electric traction drive is carried out in the paper. The options of development of the optimized asynchronous engine control systems are considered and their main shortcomings are also revealed. The purpose of this paper is development of the optimized system of the asynchronous electric drive control that will allow reduction of losses in the course of electromagnetic conversion of energy in the asynchronous tractive engine. The result of synthesis of vectorial control system optimized by criterion of a maximum of electromagnetic moment in case of the specified current of the stator of the asynchronous tractive engine is presented. The distribution function of optimum angle of current vector position of the stator in relation to vector of current linkage of a rotor of the asynchronous engine is shown. For checking the obtained control system, the imitating model in the software environment MATLAB is developed. Results of modeling of the asynchronous traction electric drive operation on the basis of the asynchronous tractive engine AD-906 are given in the mode of acceleration and electrodynamic braking in case of different values of power delivered
Key words: ASYNCHRONOUS ENGINE, MATHEMATICAL MODELING, VECTOR CONTROL

Introduction

When development of systems of the asynchronous electric drive control, the necessary task is rational use of parameters of the asynchronous engine in different operation modes [1]. One of methods of such systems creation is energy efficient vectorial control, where change of value of current linkage of rotor of the asynchronous engine takes place. The principle of a method consists in maintaining the relative position of vectors of the stator current and current linkage of a rotor; therefore, an optimum ratio of torque-forming values available to control will be found out.

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Analysis of researches and publications

Implementation of the energy efficient algorithms is connected with computer-assisted retrieval in the course of operation of electric drive of an optimum criterion extremum; it depends on several variables at the same time and requires the considerable computing opportunities of control system. This problem can be solved due to application of predetermined optimum ratios of vectors of TAD on the basis of the current information on variables of its parameters that will allow us to create the extremal control systems considering nonlinearity of a magnetic circuit and loss in TAD steel if necessary [1]. Therefore, in case of synthesis of control system, it is necessary to determine a variable, which can be used for adjustment under condition of optimization, which would be the general for torque-forming of vectors. According to [2], such variable is the angle γ of position of the stator current vector in relation to vector of current linkage of rotor.

The control system, which is provided in [3], implements function of correction of longitudinal projection of current of the asynchronous engine stator for achievement of optimum situation by an angle of position of stator current vector according to the selected criterion of optimization. Such approach requires the use of additional units of restriction of problems of projections of current vector, units of calculation of the value of angle of position of stator current vector and others that complicate the mathematical treatment of a control system.

The control systems described in [4, 5] allow one to implement energy-efficient control systems of the asynchronous electric drive, however there is a row of the considerable shortcomings that narrow the sphere of their application. In particular, the possibility of operation of the electric drive with the delivered power is not considered in these systems because it is lower than nominal one and a possibility of operation by rotor rotating speed, which exceeds nominal one, i.e. in the mode of field weakening is not considered as well.

The objective of this paper is development of the control system of the asynchronous traction electric drive optimized by criterion of a maximum of electromagnetic moment in case of the specified current of the stator; it will allow reduction of losses in the course of electromagnetic conversion of energy in the asynchronous tractive engine.

Main part of research

The diagram of the asynchronous tractive electric drive presented in a Figure 1 consists of the three-phase autonomous inverter of tension AI, sensors of currents of the phases B3, B4 and the rotational speed sensor of a rotor of the asynchronous engine B5, the asynchronous engine with a short-circuited rotor M, control system CS, the tractive generator G, uncontrollable rectifier UR, unit of sensors of value and frequency of the linear stress of tractive generator 6, the intermediate filter F, the braking chopper VT7, brake conductivity *Rt*, a regulation key of the tractive generator excitation VT8, the sensor of input current AI V2, the sensor of input voltage AI V1.

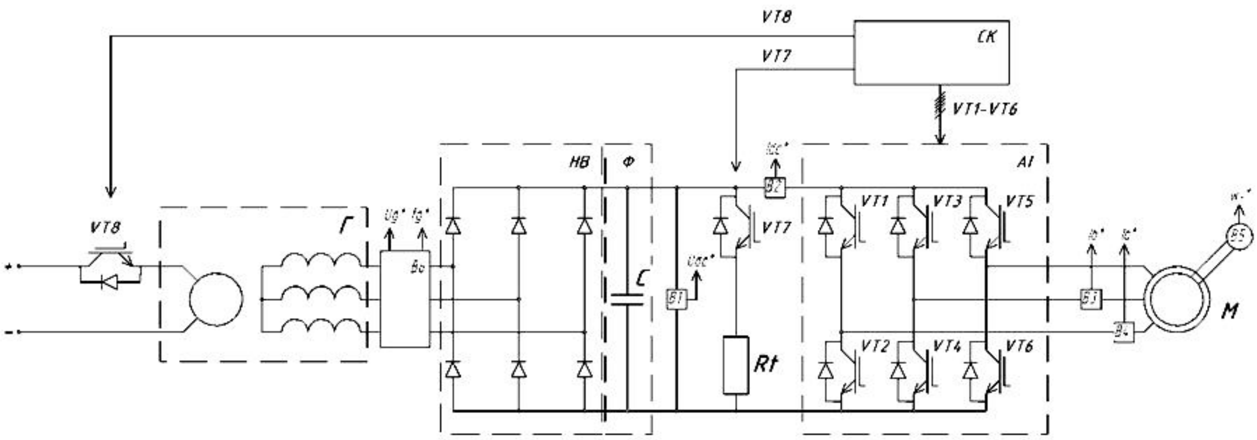

Figure 1. Scheme of the asynchronous traction electric drive

The control system is provided in a Figure 2 and consists of the unit of setting of an operation mode KM which output signal passes to rotating speed calculator, which creates setting of shaft speed of the drive engine (diesel) rotating generator G. The discrete signals of operation modes are formed by logic unit depending on the signal; signals are the following: J_T in the traction mode or J_B in the mode of electrodynamic braking.

The power calculator forms a signal of the deviation of set power depending on an operation mode and shaft speed of the generator and current power consumption by the independent inverter AI. The signal of a deviation passes to a power regulator.

The output signal of power regulator I_1 passes to a calculator of stator current vector module.

The unit of back couplings and filtering executes filtering the signals that pass from sensors of currents and tension. The signals from sensors of phase currents B3 and B4 turn from a fixed coordinate system into orthogonal one that rotates synchronously with a vector of current linkage of rotor.

The signals obtained after filtering are used for calculation of necessary variables, such as inductivity of magnetization L_m calculated depending on value of projection of current on a longitudinal axis of a coordinate system, and considers a saturation effect of magnetic system of the asynchronous engine [6]. Approximation of a magnetization curve is executed by a polynomial method by means of a polynomial of the 4th order.

Calculation of restriction value of the module of a vector of current linkage of the asynchronous engine rotor is carried out by the calculator Ψ_R and is executed as rotating speed of a rotor taking into account the mode of field weakening.

The T_R calculator executes calculation of a constant of time of rotor without change of value of the pure resistance of a rotor of the asynchronous engine. For operation modeling, it does not lead to errors of the obtained results, but if necessary, the algorithm of adjustment of value of the pure resistance of a rotor, for example with the use of Kalman filter, can be implemented by the T_R calculator [7].

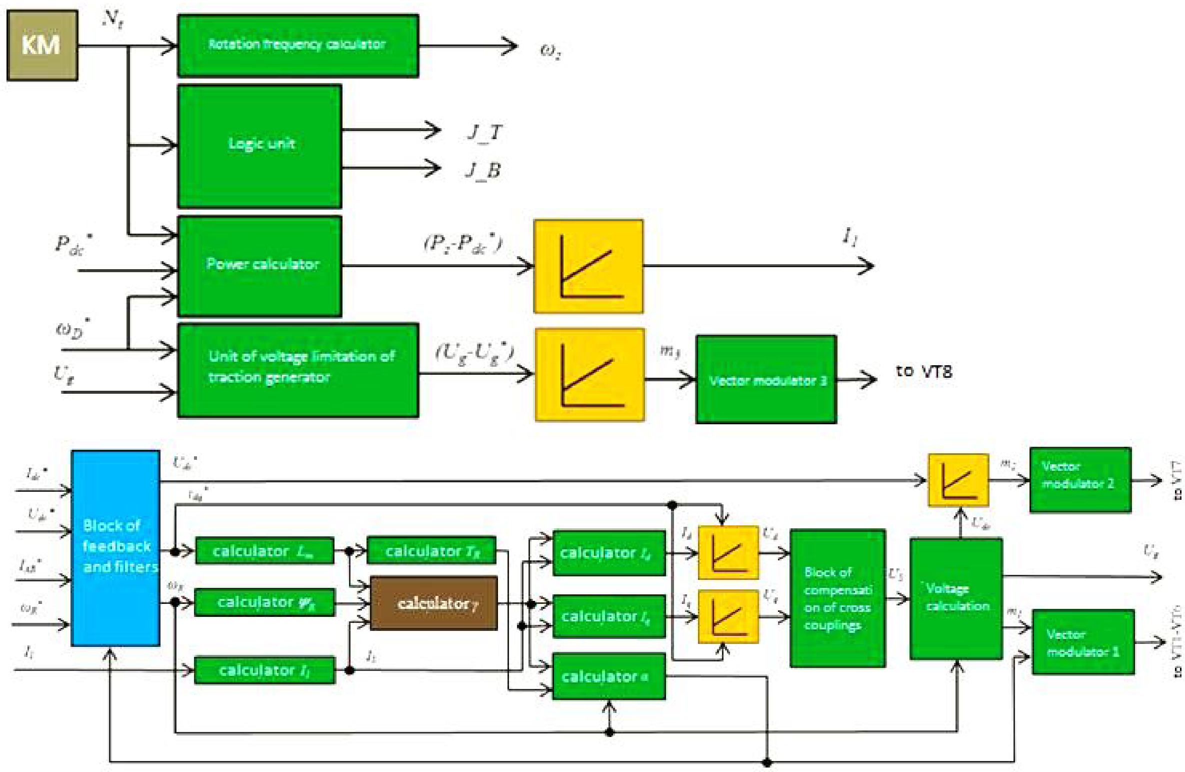

Figure 2. Control system of the asynchronous traction electric drive

The calculator γ implements search of an optimum angle according to criterion of a maximum of the electromagnetic moment in case of the specified current of the stator. In case of creation of a system of the asynchronous engine equations, connected to a vector of current linkage of a rotor, the equation holds true:

$$\Psi_R = I_{sd} \cdot L_m \tag{1}$$

Considering that

$$I_{sd} = |I_s| \cos\gamma \tag{2}$$

$$I_{sq} = |I_s| \sin\gamma \tag{3}$$

Then

$$\Psi_R = |I_s| \cdot \cos\gamma \cdot L_m \tag{4}$$

Let us rewrite the obtained equation relatively to γ:

$$\gamma = arccos\frac{\Psi_R}{I_s \cdot L_m} \tag{5}$$

Apparently from a formula (5), the angle of mutual position of vectors of current of the stator and current leakage of rotor γ is function of three variables and is presented in Figure 3. The upper bound of restriction of angle is determined by extreme firmness of the asynchronous electric motor in a zone of field weakening.

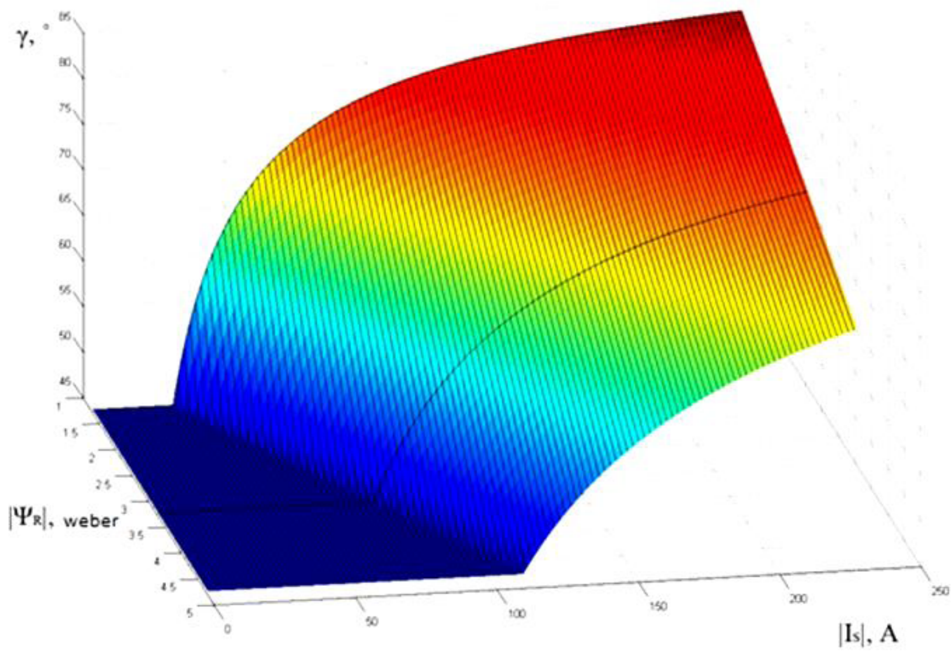

Figure 3. Function of torque angle *γ*

Check of reaching extremes of function of electromagnetic moment [7] taking into account equations (3)

$$M_{el} = \frac{3}{2} Z_p \frac{L_m}{L_R} \Psi_{Rd} I_s \sin\gamma \qquad (6)$$

confirms that the selected equation (5) completely meets a condition of an extremum of the electromagnetic moment in case of constant value of the module of current vector of the asynchronous engine; this is the selected criterion of optimization of management system.

For a task of projections of current of the stator in calculators units *Id* and *Iq*, we use formulas (2) and (3) respectively. Signals of deviation of value of the current projections of current vector from set by calculators *Id* and *Iq* are input signals of regulators of power.

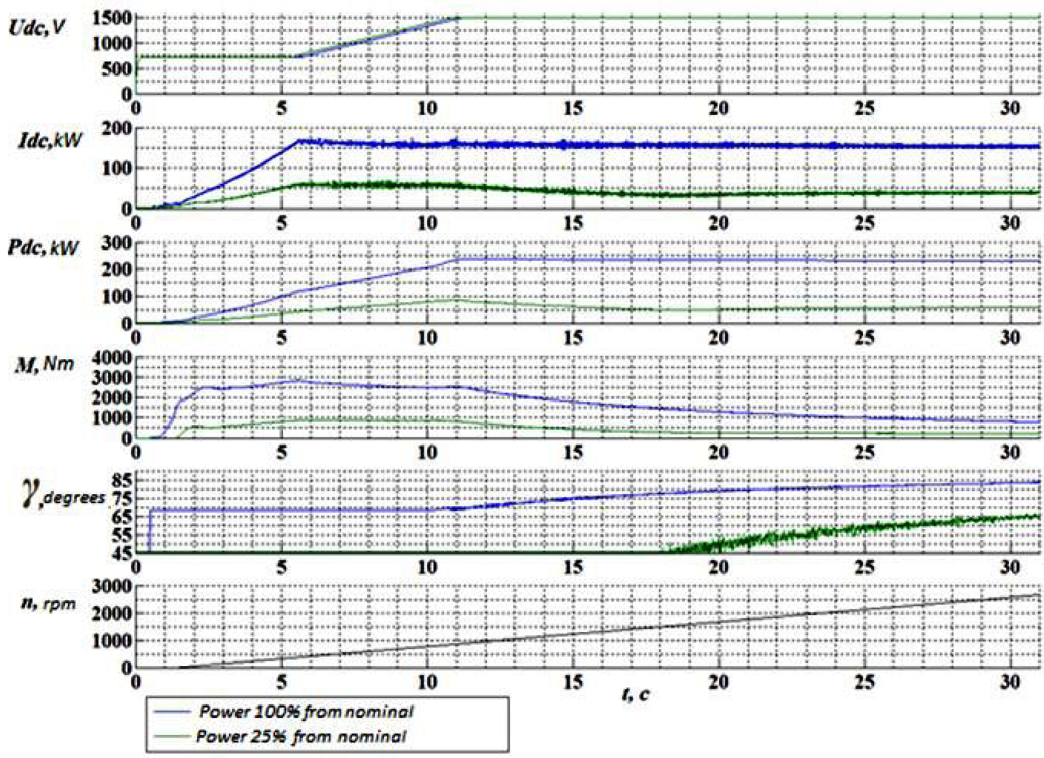

Figure 4. Transient process when accelerating the asynchronous engine AD-906

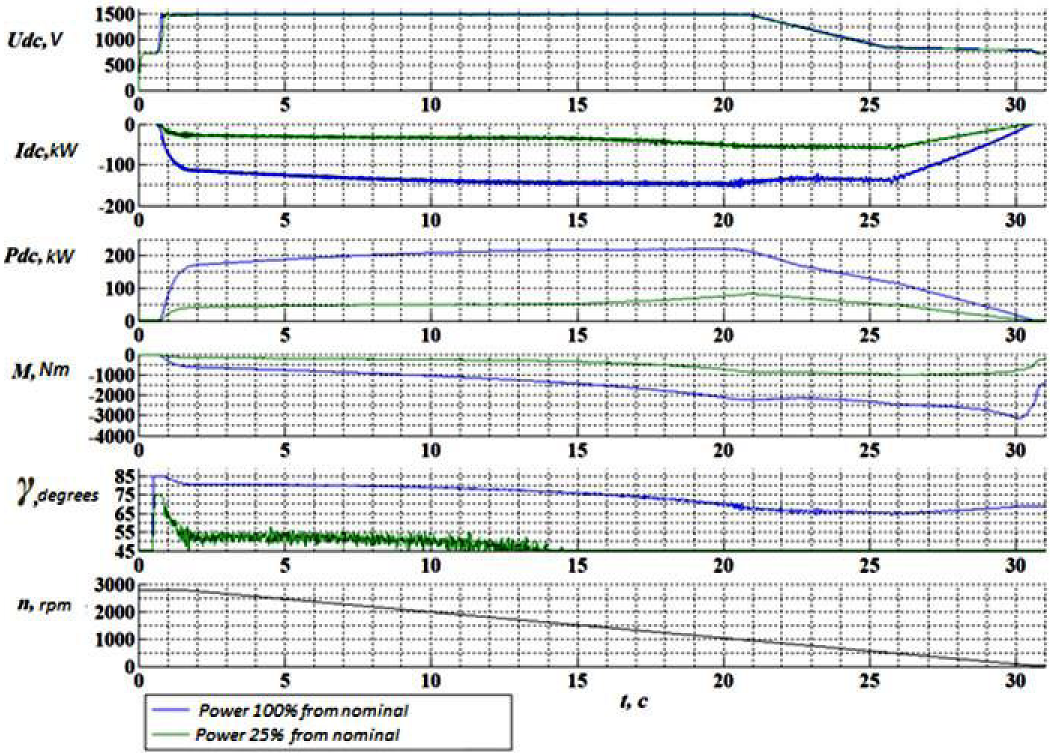

Figure 5. Transient process when electrodynamic braking of asynchronous engine AD-906

Outputs of current regulators are connected to an input of cross couplings compensating unit [8], on which output signal of value of the vector module of tension of the stator of the asynchronous engine is formed. The obtained signal is supplied to the input of tension calculator, which depending on the current frequency rate of rotation of a rotor of the asynchronous engine forms signals of tension setting for the tractive generator, input voltage of the autonomous inverter in the mode of electrodynamic braking, and voltage output of the autonomous inverter.

For check of operation of the suggested control system of the asynchronous tractive electric drive, we will use a simulation model in software environment MATLAB.

In Figures 4 and 5, transient processes of traction modes and electrodynamic braking of AD-906 engine are presented. Range of change of rotation speed of engine rotor is from the maximum operating to of zero in the traction mode and 19.3 rpm in the mode of electrodynamic braking.

Conclusions

The suggested control system of asynchronous tractive electric drive with maintenance of an angle of mutual position of stator current vectors and current linkage of a rotor is conductive to minimization of losses of the electric power by operation of the asynchronous engine.

The conducted research of operation of asynchronous traction electric drive with the suggested control system in a simulation model in a software environment MATLAB showed that operation in case of value of delivered power 25% of nominal is followed by maintenance of an angle of mutual position of stator current vectors and current linkage of rotor at the level of 45° that according to [2] is a condition of minimization of losses by operation of the asynchronous engine.

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