Calculation of traction induction motor using dynamic model of the field

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Abstract: **In addition to the traction mode, important modes of traction induction motors are start by underfrequency relay and braking. An important objective in the design of engines of this type is the calculation and optimization of engine characteristics in these modes. Field dynamical models allow to reach the most complete account of the structural features and physical effects during the calculation of characteristics.**

Keywords: **Traction induction motor, finite-element model, dynamical model, calculation time, parallel computing.**

When designing asynchronous traction motors unique requirements are set to the form of the curve of the mechanical characteristic and the value of the starting current, in particular during start by underfrequency relay. Analytical models are often used on this stage. Their common drawback is the large number of assumptions taken.

Currently numerical models based on the application of results of magnetic field calculation in the equations of the equivalent circuit are getting more and more popular. Such models automatically take many factors into account, including the design features, the nonlinearity of the magnetic characteristics of the materials and the effect of the current displacement [1]. The problem of application of such models in the design of asynchronous traction motors is pressing.

In order to implement a field dynamical model an original library of finite element modeling of the magnetic field «EMLib» was developed. It includes means for parametric generation of finite element models. Usage of «EMLib» allows to create compact modeling tools that are compatible with other applications.

In order to calculate transient processes in an asynchronous machine a number of iterations with a time step Δt should be made. At each iteration a system of equations in matrix form (1) should be solved.

$$L \cdot \frac{d}{dt} x = U, \qquad (1)$$

where x - a vector of the unknown values - the currents in the circuits of the stator and rotor windings, turning angle and speed of rotation of the rotor. For the three-phase motor with a squirrel cage elements of the system (1) have the form:

$$U = \begin{vmatrix} U_{12} - i_1(r_1 + r_3) - i_2 r_3 \\ U_{23} - i_2(r_2 + r_3) - i_1 r_3 \\ \\ -i_4 \cdot \left(r_4 + r_{4+n} + r_{\sigma 4} + r'_{\sigma 4}\right) + i_{N+1-n} r_4 + i_{4+n} r_{4+n} \\ \dots \\ -i_N \cdot \left(r_N + r_{3+n} + r_{\sigma N} + r'_{\sigma N}\right) + i_{N-n} r_N + i_{3+n} r_{3+n} \\ \Omega \\ \frac{M}{J} \end{vmatrix} \qquad (2)$$

$$L = \begin{vmatrix} L_{11} - L_{31} + L_{\sigma 1} + L_{\sigma 3} & \dots & \dots & L_{1j} - L_{3j} & \dots & L_{1N} - L_{3N} & \frac{\partial \Psi_1}{\partial \alpha} - \frac{\partial \Psi_3}{\partial \alpha} & 0 \\ L_{21} - L_{31} + L_{\sigma 3} & \dots & \dots & L_{2j} - L_{3j} & \dots & L_{2N} - L_{3N} & \frac{\partial \Psi_2}{\partial \alpha} - \frac{\partial \Psi_3}{\partial \alpha} & 0 \\ L_{41} & \dots & \dots & L_{4j} & \dots & L_{4N} & \frac{\partial \Psi_4}{\partial \alpha} & 0 \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots & 0 \\ L_{N1} & \dots & \dots & L_{Nj} & \dots & L_{NN} + L_{\sigma N} + L'_{\sigma N} & \frac{\partial \Psi_N}{\partial \alpha} & 0 \\ 0 & \dots & \dots & 0 & \dots & 0 & 1 & 0 \\ 0 & \dots & \dots & 0 & \dots & 0 & 0 & 1 \end{vmatrix} \qquad (3)$$

In the matrixes (2), (3) elements with index σ – reactance resistances calculated during the design calculation. The elements of the matrix (3) are calculated during the finite element calculation of the field on every iteration.

This model allows the calculation of the dynamic characteristics with different laws of change of the applied voltage and frequency. It is well suited for modeling the start-up and braking of traction induction motor in the course of checking calculation.

In addition to calculating the dynamical characteristics of the motor, the developed model can be used to calculate the mechanical characteristics. In order to obtain the values of the electromagnetic torque for different rotor speeds, resultant torque M in the matrix (2) should be set to 0. Also it is necessary to set the angular velocity Ω. After that, an iterative calculation should be conducted until the transient process ends. After that, the current torque value should be recorded, and the value of Ω should be changed. The disadvantage of this method is the large amount of time required to calculate the mechanical characteristics.

Calculations for different speed values can be performed independently. This allows to implement parallel computing with the use of multi-processor technology when determining the mechanical characteristics. In this case, the calculation time may be seriously reduced.

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REFERENCES

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