# Improvement of computation speed of finite-element model of induction machine dynamics with the use of parallel computing technology

Yu.B. Kazakov, A.I. Tikhonov, L.N. Bulatov

Faculty of Electromechanics, Ivanovo State Power University, Rabfakovskaya street 34, Ivanovo, Russian Federation,
e-mail: elmash@em.ispu.ru

***Abstract*: Suggested is a method of improvement of computation speed of finite-element model of induction machine.**

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In order to perform precise analysis of induction machine (IM) dynamics high-speed electromagnetic model is required. This model should be precise and allow to take physical phenomena such as deep-slot effect in cage rotor and steel saturation effect into account. Finite-element based models satisfy these requirements.

IM dynamics may be defined with the system of equations:

$$\begin{cases} \frac{d}{dt}\Psi = U - RI \\ \frac{d^2\alpha}{dt^2} = \frac{\Sigma M}{J} \end{cases} . \quad (1)$$

Magnetic flux linkage of winding/circuit k incrementation can be defined as:

$$\frac{d\Psi_k}{dt} = \sum_{j=1}^{n} \frac{\partial \Psi_k}{\partial i_j}\frac{di_j}{dt} + \frac{\partial \Psi_k}{\partial \alpha}\frac{d\alpha}{dt} = \sum_{j=1}^{n} L_{kj}\frac{di_j}{dt} + \frac{\partial \Psi_k}{\partial \alpha}\Omega \ . \quad (2)$$

After transformations (1) may be presented as:

$$\frac{di}{dt} = L^{-1}(U - Ri) \ , \quad (3)$$

*di/dt* – one dimensional array of currents in windings/circuits incrementation and rotation speed incrementation; L - square matrix of induction coefficients (represents influence of currents and rotation speed alteration on magnetic flux linkage).

$$L_{kj} \approx \frac{\Delta\Psi_k}{\Delta i_j}, \quad \frac{d\Psi_k}{d\alpha} \approx \frac{\Delta\Psi_k}{\Delta\alpha} \ . \quad (4)$$

Elements of matrix L are to be redefined with the use of finite-element model of IM magnetic field on every step of iteration while solving equations system (1). In order to do this N+2 finite-element calculations of magnetic field are conducted, where N – number of circuits with current. This way it is possible to take steel saturation effect into account. In order to take deep-slot effect into account rods of rotor should be split into several layers throughout the height in the model.

Described model [1] allows to reach useful-level accuracy. The main disadvantage of the model is significant calculation time due to multiple finite-element calculations that should be performed on every step of iteration. There are several ways to increase calculation speed: increase of time differentiation step; reduction of number of elements in finite-element model; simplification of model within one iteration (since conditions of separate finite-element calculations within current iteration are close, results of one calculation may be used to increase speed of the next). These ways allow to increase calculation speed, but decrease precision of the model.

Calculation speed may be increased by up to 15% with the use of implicit 2th-order Adams-Moulton method. In the developed algorithm [2] time differential for the following moment of time if automatically changed, recalculated, and taken into account on each iteration. This way there is no need to keep two separate arrays of time differentials for two next moments of time in the memory of the model.

In order to achieve further increase in calculation speed parallel computing technology may be used. It is possible since all finite element calculations within single iteration may be performed separately [2]. One element of computer cluster is chosen as the main. It is used to solve system of differential equations (1), accumulate data and synchronize work performed by other processes. All other processes are marked as secondary and are used for finite-element calculation of magnetic field.

In order to reach maximum performance, calculation time of different processes should be the same. This is important for effective usage of multiprocessor computers, because this way idle time of the processes caused by asynchronous calculation completion is reduced. Data sharing between processes is accomplished in the beginning of calculation and in the end of every iteration.

The model is implemented with the use of programming language C and MPI standard. Model is tested on the computer cluster "Energet" situated in ISPU. Usage of parallel computing technology allows to increase calculation speed significantly. Maximum performance is reached when number of parallel processes is equal to number of circuits with current + 1 (N + 1). This allows to increase calculation speed in more that N/2 times.

## Conclusion

Usage of parallel computing technology allows to increase calculation speed of finite element model of IM dynamics significantly, without any affect on original precision of the model.

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