Induction Motor Characteristics Taking into Account the Variations of Magnetic System Properties

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Abstract Induction motor equivalent circuits, as well as improved mathematical models, taking into account the magnetizing curve nonlinearity, the phenomena of hysteresis and eddy currents, have been proposed. Induction motor static, power and dynamic characteristics have been researched taking the mentioned phenomena into consideration. A harmonic analysis of induction motor currents under no-load conditions has been carried out. It has been demonstrated that taking magnetizing curve nonlinearity into account in the mathematical model results in coincidence of characteristics obtained at the mathematical model and experimental curves. The eddy currents losses increase influence on induction motor characteristics has been shown. The adequacy of the proposed mathematical model has been confirmed by experimental research.

Keywords: induction motor, mathematical model, steel losses, magnetizing curve nonlinearity, hysteresis, eddy currents.

I. INTRODUCTION

The necessity of active materials efficiency improvement, as well as wide application of induction motors (IM) forced operation, expands the sphere of its work under the nonnominal conditions when magnetic system is saturated.

Deterioration of electric steel properties, due to its ageing and change during the process of repair, also results in IM operation with significant degrees of saturation. This is accompanied by current form distortion and increase of steel power losses due to higher harmonics [1]-[2]. Such deviation of operation conditions parameters from the nominal ones causes the necessity of creating improved mathematical models for IM design and formation of efficient conditions for their work.

According to the above said, the purpose of the paper consists in improvement of IM mathematical models in order to research its characteristics taking into account the magnetizing curve nonlinearity, phenomena of hysteresis and eddy currents.

II. MATERIAL AND RESEARCH RESULTS

To analyze IM characteristics, taking into account the magnetizing curve nonlinearity, the phenomena of hysteresis and eddy currents, an equivalent circuit (Fig. 1) has been proposed. In this equivalent circuit r_1, x_1 – respectively, stator active and inductive resistance; r_2', x_2' – respectively, rotor reduced active and inductive resistances; r_{ed}, x_{ed} – respectively, active and inductive resistance to eddy currents; r_μ – magnetizing circuit active resistance; x_μ – magnetizing circuit inductive resistance depending on magnetizing current, $x_\mu(I_\mu)$; s – IM slip.

To research IM dynamic characteristics a mathematical model in a three-phase coordinate system has been created. A method for nonlinear characteristic analytical approximation has been used for mathematical description of magnetizing circuit inductance variation curve. Hysteresis influence is taken into account using an aperiodic link whose time constant makes it possible to vary the hysteresis loop width and reflects the magnetizing process inertia.
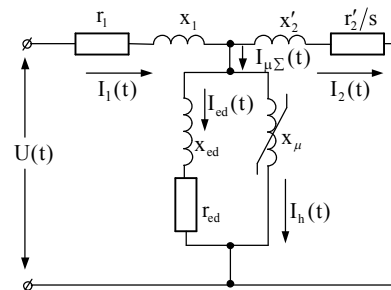

Fig. 1. IM equivalent circuit taking into account
the division of the magnetizing circuit into components

Experimental research was carried out to confirm the results obtained by mathematical modeling. The experimental facility included: a step-up autotransformer providing a saturated condition of the motor; current and voltage sensors; an analog-digital converter; an investigated motor. Estimation of eddy currents influence on IM characteristics was made by imitation of stator teeth steel sheets shorting by means of foil.

The adequacy of the offered mathematical model has been verified by comparison of experimental results with the results obtained at the mathematical model.

III. CONCLUSION

IM equivalent circuits have been proposed and mathematical models taking into account the magnetizing circuit nonlinearity, eddy currents influence, hysteresis loop width have been created, which makes it possible to obtain IM characteristics when magnetic system parameters are changed. The created IM mathematical model with division of steel power losses into components enables one to estimate eddy currents and hysteresis influence on general steel losses.

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