Core losses estimation in induction motor supplied by frequency converter with pulse width voltage modulation

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Abstract: **Core losses estimation in the induction motor was performed using analytical method and finite element method.**

Keywords: **Induction motor, core losses, losses increasing coefficient, pulse width voltage modulation.**

I. INTRODUCTION

Nowadays, induction motors are often supplied by semiconductor frequency converters with pulse-width voltage modulation. These frequency converters produce impulse output voltage which harmonic content contains the higher harmonics. High-frequency harmonics cause additional losses in induction motor cores, and accurate estimation of core losses increasing is actual issue.

II. CORE LOSSES ESTIMATION

Existent calculation procedures for core losses estimation in the induction motors supplied by pulse width modulated voltage are based on simplify engineering approach, which do not consider decomposing of core losses into hysteresis and eddy-current components [1].Calculation procedure proposed in this article allow accounting of core loss decomposing into the components. Since hysteresis losses are proportional to the first power of frequency, and eddy-current losses are proportional to the square of frequency, proportion between them will vary with increasing of frequency.

For high-frequency harmonics the demagnetization effect of eddy current takes place. This effect causes eddy current losses reducing by amount ξ. For ν-order harmonic, this coefficient can be found as:

$$\xi_\nu = \frac{3\delta}{d} \cdot \frac{sh\left(\frac{d}{\delta_\nu}\right) - sin\left(\frac{d}{\delta_\nu}\right)}{ch\left(\frac{d}{\delta_\nu}\right) - cos\left(\frac{d}{\delta_\nu}\right)}$$

where δ_ν – penetration depth of electromagnetic wave into laminated sheet; d – thickness of laminated sheet.

For fundamental core losses, the coefficient of core losses increasing can be defined by expression:

$$K_{fund} = 1 + \sum_{\nu=5}^{\infty} \left(\frac{U_\nu}{U_1}\right)^2 \cdot \frac{1}{\nu} \cdot \frac{\left(\frac{\pi^2 \cdot d^2 \cdot \xi_\nu}{6\rho_{st} \cdot \gamma_{st}} \cdot f_1 \cdot \nu + K_h\right)}{\left(\frac{\pi^2 \cdot d^2}{6\rho_{st} \cdot \gamma_{st}} \cdot f_1 + K_h\right)}$$

where U_ν – magnitude of ν-order harmonic; U_1 - magnitude of fundamental; f_1 – frequency of the fundamental harmonic; ρ_{st} – steel conductivity; γ_{st} – steel mass density.

Hysteresis loss coefficient K_h can be found as:

$$K_h = \frac{p_{st.rated}}{B_{eqv}{}^2 \cdot f_1 \cdot m_{st}} - \frac{\pi^2 \cdot d^2 \cdot f_1}{6\rho_{st} \cdot \gamma_{st}}$$

where $p_{st.rated}$ – fundamental core losses in the induction motor with sinusoidal supply voltage; B_{eqv} – equivalent average amount of flux density in stator core; m_{st} – stator core mass.

Total core losses increasing coefficient can be defined by following expression:

$$K_{st} = \frac{p_{st.rated} \cdot K_{fund} + p_{st.add}}{p_{st.rated} + p_{st.add}}$$

where $p_{st.add}$ – additional core losses.

It is reasonable to use the finite element method for considering the actual distribution of flux density over induction motor cores. Core loss increasing coefficients were calculated using finite-element simulation of electromagnetic field in 170 kW induction motor. These coefficients were calculated for four supply voltage waveforms. Calculation results are summarized in Table I.

TABLE I.
CORE LOSS INCREASING COEFFICIENTS

Supply voltage waveform	K_{st}	
	Analytical calculation	Numerical calculation
With constant width of impulses	1.124	1.570
With sinusoidal width of impulses	1.056	1.061
With sinusoidal height of impulses	1.134	1.145
With pulse-step height of impulses	1.061	0.861

III. CONCLUSION

Core loss increasing coefficients were estimated using analytical method and finite-element method. Relative errors between results obtained by these methods do not exceed 28.4%.

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