Quantitative Study on the Electromagnetic Vibration in a Squirrel-cage Induction Motor

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1. Introduction

Squirrel-cage induction motors have been widely used as constant-speed motors in many industrial applications for a long time. However, high performance speed control technology has advanced in recent times, with the result that vector-controlled squirrel-cage induction motors have been widely applied to variable speed driving systems (1),(2). Together with this increase in the use of induction motors have come increased requirements for much lower vibration and acoustic noise levels. As a result, a great deal of research on methods of reduction for both acoustic noise and vibration has been published (3)-(5).

In squirrel-cage induction motors, the airgap magnetic flux density includes many harmonic components (other than fundamental component) due to harmonic magnetomotive force caused by winding and harmonic airgap permeance caused by slot opening. Harmonic torque, loss(6) and radially-directed electromagnetic forces (mentioned in this paper) are generated due to interaction of the airgap with the harmonic magnetic flux density. It is not the probability of harm, but rather the scale of the harm potentially due to these harmonics that makes them worthy of study. Therefore, it is necessary to quantitatively determine the factors which affect these harmonics (and their associated vibration and acoustic noise levels) with which to base design improvements for lower-noise squirrel-cage induction motors.

In this paper, concept for quantitative study of the radially-directed electromagnetic forces which cause both vibration and acoustic noise will be offered and quantitative analytical expression will be shown. We will show the main factors causing the generation of these radially-directed electromagnetic forces, at the same time we shall describe how to perform quantitative calculations with respect to electromagnetic forces, vibration levels, and flexural vibration of the stator core. Then, the utility of the theoretical models will be evaluated by comparing calculated theoretical values against actual measured values. These include: variations in amplitude of vibrations in the stator core – vibrations due to variations in, for example, supply frequency and supply voltage.

2. Concepts Related to Radial Electro-magnetic Forces and the Quantitative Expression

2.1 General expression of the Radial Force

2.2 Simplified Expression for Analysis of the Radial Force in the No-Load Steady-State and Consideration of the Factors Affecting the Radial Force

3. Theoretical Analysis of Electromagnetic Vibration due to the Radial Force

4. Comparison of Theoretically Calculated Value and Measured Value of Vibration in the Stator Core

4.1 Main Specifications and Radial Force of the Model Motor

4.2 Relations between the Stator Core Vibration and the Supply-Frequency, and Supply-Voltage

5. Conclusion