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Induction Motor Capacitances Calculation Using FEA for Common Mode Current Studies in ATP

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Abstract. The prediction of common-mode currents in inverter-driven induction motors is necessary to propose mitigating solutions in order to prevent failures and ensure the proper operation of the entire electrical system. The motor model for these high-frequency studies is relatively simple; however, to find its parameters accurately is a very complex task. In this context, this paper presents an alternative to estimate leakage capacitances in induction motors, based on the finite element technique, through computational simulation using FEMM (Finite Element Methods Magnetics). Then, an application of the motor capacitances in an appropriate model for common-mode quantities determination is shown as an example, using the ATP (Alternative Transients Program).

Key words

ATP, common-mode currents, FEMM, high-frequency induction motor model, leakage capacitance calculation.

1. Introduction

The power quality is a subject that does not only consider the standard waveforms of the supplied voltage, but also the good performance of electrical machines. These are always being analyzed due to their great relevance and contribution to the electrical system. The study of side effects of the joint operation between induction motors and inverters, aiming to improve the system performance, efficiency and control, is necessary to prevent the decrease of the motor lifetime and also for protection equipment specification and EMC issues.

Regarding three-phase PWM inverters, it is well known that the instantaneous combination of its output phase voltages is a non-zero value. This resulting voltage is characterized by a step waveform, which variations (dv/dt) correspond to one third of the DC link voltage of the converter. Each variation of this common-mode voltage excites the capacitive couplings between connecting cables, converter and motor to the ground, providing the circulation of common-mode currents [1]. These currents are responsible for the improper operation of fault-to-ground relays, electromagnetic interference (EMI) and bearing failures, among other problems [2, 3].

Concerning the motor, its model for the study of these high-frequency phenomena is based on an equivalent electrical circuit [4], where its internal capacitive couplings are included, such as the ones between stator windings and frame (C_{sf}), stator windings and rotor (C_{sr}), rotor and frame (C_{rf}) and bearings (C_b). For the capacitances C_{sf} and C_{rf}, displacement currents are established for each variation of the common-mode voltage. Through the bearings, discharge currents are generated whenever the induced electrostatic voltage on the machine shaft is high enough to disrupt the dielectric rigidity of the lubricant grease. Its effect is to damage the bearing balls and races, taking it to premature failure [3, 4].

Despite the simplicity of the motor equivalent circuit including its capacitances, the determination of these parameters shows to be a complex task. Measurements require expensive instruments and implicate in practical difficulties [5], which turn the procedure into something generally impracticable. On the other hand, analytical formulation [5, 6] does not provide accurate results, since several simplifications are made in its derivation.

In this context, this paper presents an interesting alternative, based in the Finite Element Method, to calculate the capacitances C_{sf}, C_{sr} and C_{rf} through the software FEMM (Finite Element Methods Magnetics). In sequence, the application of such capacitance values in