

General Approach for Homogenisation of Multi-turn Windings in Three-dimensional Finite Element Models

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ABSTRACT

In this paper the authors present a general approach for homogenising a winding in a three-dimensional (3D) FE model of an electromagnetic device. The frequency-domain homogenisation is based on a complete eddy current characterisation of the winding (type of conductor cross-section and packing, fill factor) by means of a simple two-dimensional (2D) finite-element (FE) model. This model contains an elementary cell (one conductor cross-section plus insulation) and a number of layers of identical cells surrounding it. Skin or proximity effect is effected in the central cell by means of an imposed nonzero current (or average current density) in all conductors or by a boundary conditions corresponding to an average induction in either of two perpendicular directions. This way the active and reactive power consumption of the winding cells can be captured in two dimensionless and frequency-dependent skin-effect coefficients, and in four (or two, in the isotropic case) proximity effect coefficients.

In a 2D or 3D FE analysis of a complete device, the skin and proximity effect in the windings are accounted for by adopting complex and frequency dependent values for the resistance and the reluctivity. These values follow directly from the six or four dimensionless coefficients determined using the elementary 2D FE model.

By way of validation the homogenisation method is applied to a 3D FE model of an axisymmetric 120-turn inductor. A round conductor with square packing is considered. The magnetic core is either closed or has a central airgap. The results obtained with this method are compared to those supplied by a 2D FE model in which all turns are discretised separately, thus allowing the direct and precise consideration of skin and proximity effect. An excellent agreement is observed.

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