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Field–circuit coupled models in electromagnetic simulation

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Abstract

A general field–circuit coupling mechanism for electromagnetic models is presented. The topological treatment of the circuit allows for a well-defined choice of coupling unknowns and equations, both for couplings of magnetic fields to magnetic circuits and couplings of magnetic fields to electric circuits. The properties of the resulting systems of equations are studied and appropriate iterative solution techniques are proposed. Three technical examples demonstrate the modelling flexibility provided by field–circuit coupling.

Keywords: Coupled problems; Electromagnetic simulation; Finite element method; Circuit simulation; Electrical machines

1. Introduction

Circuit simulation is close to technical understanding, offers fast models, but requires skilled engineers to derive appropriate lumped parameters for insertion in the circuit model. A simulation approach based on a discretisation technique is more suited for models with arbitrary geometries, complicated excitations, eddy currents and ferromagnetic saturation, it is commonly automated up to a certain extent, but it may require a considerable computational effort. For many electrotechnical problems, a circuit model may provide a sufficient accuracy for a part of the model, whereas the remaining part requires a two-dimensional or three-dimensional discretisation, e.g., by the finite element (FE) method (Fig. 1). In that case, hybrid field–circuit coupled models offer an optimal

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