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Electric field computation in non conducting regions using AV after a t_0-ϕ surface impedance magnetoharmonic computation

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Abstract— This paper presents a model for calculating electric field in non conducting regions in steady state AC magnetic application, with conductors described by surface impedance, using the 3D finite element method. This approach is validated by calculating the equivalent impedance of a coil comparing the presented surface impedance decoupled method with a volume decoupled method.

I. Introduction

In some applications, it is necessary to know the electric field in non conducting regions (air or dielectric regions), after a 3D AC steady state magnetic computation. The electric field is assumed to have no meaningful feedback into the magnetic field. For instance, it is the case for the simulation of the measure of a voltmeter between inductor turns or between sectors of cold crucibles, or when the capacitive effects of coils have to be computed in addition to resistive and inductive effects. A previous work dealt with a decoupled model for the computation of electric field in non-conducting regions after a steady state AC magnetic computation using the 3D finite element method, where the conductors were meshed and described by Tϕ formulation [1] (method derived from [2]). This method was validated with simulations solving full Maxwell's equations. The cold crucibles are around 2 meters long. At their working frequencies (around 300 kHz), the skin depth is small and the inductors and sectors must be described by the surface impedance formulation [3]. This paper presents the extension of the method presented in [1] for conductors described by surface impedance with magnetic scalar potential ϕ as state variable. They can be coupled with an external circuit.

II. Numerical Method

Let Ω_{nc} be the non conducting region (air and dielectric regions), Ω_c the conducting region described by surface impedance and Γ_i, its boundary. The decoupled method consists of two successive computations: 1) steady state AC magnetic computation with T_0-ϕ surface impedance formulation [3], 2) computation of electric field in non-conducting regions. The second computation consists of 2 steps, described below.

A. *First step: passage from ϕ to AV*

At the first step, the magnetic vector potential A is computed in the non conducting region Ω_{nc} and the electric scalar potential V on the surface impedance (Z_S) region Γ_i, as functions of B in Ω_{nc} and tangential H on Γ_i. To that purpose, the following functional is minimized to obtain the system of equations which are solved in this first step:

$$F = \frac{1}{2}\int_{\Omega_{nc}} (\mathrm{rot}\,A - B)^2\, d\Omega + \frac{1}{2}\int_{\Gamma_i} \frac{Z_s}{j\omega}\left[\frac{1}{Z_s}\left(j\omega A_s + \mathrm{grad}_s V\right) + n \times H\right]^2 d\Gamma \qquad (1)$$

B. *Second step: computation of electric field from AV*

At the second step, E is computed in the non conducting region Ω_{nc}. To that purpose, the Maxwell-Gauss law (div D = 0) is solved in Ω_{nc}, assuming no existing charge volume density. Therefore, V is computed in the $\Omega_{nc}\backslash\Gamma_i$ region as function of A in Ω_{nc} and V on Γ_i, solving the following equation (which corresponds to solve div D = 0):

$$\int_{\Omega_{nc}} \varepsilon\, \mathrm{grad}\, V \cdot \mathrm{grad}\, w\, d\Omega = -\int_{\Omega_{nc}} j\omega\varepsilon\, A \cdot \mathrm{grad}\, w\, d\Omega \qquad (2)$$

III. Numerical Example

The method was validated on an example with a simple geometry: a semicircular coil with a R = 2.5µm radius circular section, with imposed potentials on the terminals of the coil. As electric energy (0.5 D.E) is function of electric field, we computed the capacitance of equivalent circuit of the coil at several frequencies as in [1]. Fig. 1. depicts the capacitance function of R/δ ratio, where δ is the skin depth. Results in terms of capacitance were compared with those obtained with the previous method of [1], where the coil was meshed and described by Tϕ formulation. The presented method is considered to be validated and gives good results.

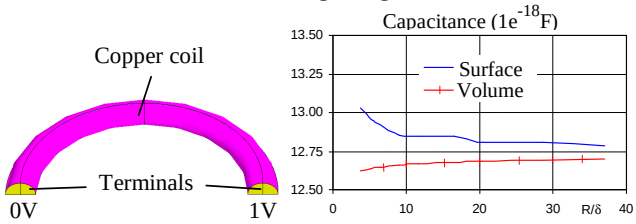

Fig. 1. Geometry of the coil and curves of capacitance function of R/δ ratio with method presented here ("Surface") and method of [1] ("volume")

IV. References

[1] P. Pham Quang, C. Guérin, G. Meunier and Y. Lembeye, "Validation of a 3D decoupled magnetodynamic – electric model by determining the impedance of microcoils", ISEF, Arras, France, September 10-12, 2009.

[2] P. Dular and P. Kuo-Peng, "Dual finite element formulations for the three-dimensional modeling of both inductive and capacitive effects in massive inductors", *IEEE Trans. Magn.*, Vol 42, No. 4, pp. 743-746, April 2006.

[3] G. Meunier, C. Guérin and Y. Le Floch, "Circuit coupled t_0-ϕ formulation with surface impedance", *IEEE Trans. Magn.*, Vol 44, No. 6, pp. 730-733, June 2008.