

Numerical Methods for Eddy Currents Modeling of Planar Transformers

Jérémie Aimé^{1,2}, Bruno Cogitore², Gérard Meunier¹, Edith Clavel¹, and Yves Marchal¹

¹Grenoble Electrical Engineering Laboratory, G2ELab, BP 46 38402 St Martin d'Hères, France

²MICROSPIRE R&D Center 38430 Molaines, France

Having many advantages compared to classic wire wound technology, planar magnetic components are largely used. Modeling tools are required to help designers for less time consuming conception. Nevertheless, number of adapted modeling solutions is limited by the complexity of such geometries. The determination of appropriate description (2D or 3D) for eddy currents modeling and by this way AC copper losses evaluation are investigated in this paper. The validity of the approach is successfully presented on an industrial application from the current evaluation until thermal simulations.

Index Terms—Eddy currents, finite element method, planar transformers, 2D and 3D electromagnetic modeling, thermal simulation.

I. PRESENTATION

THE electronics industry represented 1140 billion Euros in 2008 which is comparable to the Car industry (1800 billion in 2008) [1]. Market of wounded components represented 35 billion Euros in 2008 showing the importance of this activity domain. Today, new societal needs for energy, security or health provide long-term growth perspectives. In consequence, intensive research and development efforts must be carried on. Non insulated Switched Mode Power Supplies (SMPS) versions are very limited. Transformers provide the advantages for safety reasons of input to output insulation. Moreover, multiple outputs can be obtained. The turn ratio can also be selected to optimize the duty cycle and minimize the peak currents. But their power losses, additional weight and size are some important disadvantages. The voltage spikes due to the leakage inductance need to be considered too. The MOSFET advent in the power electronic structures implies an increase of frequency so the size of transformers can be reduced. But with the conventional wire wound technology, this is no more possible. That is why planar technology is preferred. It allows overcoming this limit. The windings of the planar components are made of Printed circuit boards (PCBs) or copper foil lead frames conferring a low profile, small volume and a high power density (Fig. 1). The windings are pre-cooled so the repeatability and predictability are improved. The leakage inductance is reduced [2]. But at high frequency operation, due to skin and proximity effects, the non-uniform current distribution leads to an increase of winding ac resistance. Moreover, considering parallel layers, induced voltages and unfortunately circulation currents are produced by difference of flux flowing through parallel layers [3].

These frequency effects must be accurately taken into account for eddy current modeling [9]. By this way AC copper losses computation is possible and consequently, thermal management. A full modeling procedure is presented in this paper. But since industrial applications are complex, an accurate 3D complete modeling is not possible. So, in the next part, the possible assumptions to limit size of problem and simulation time

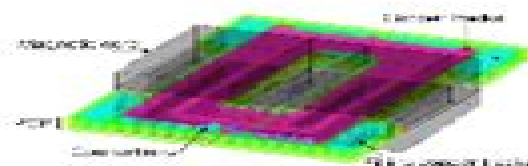


Fig. 1. Planar transformer.

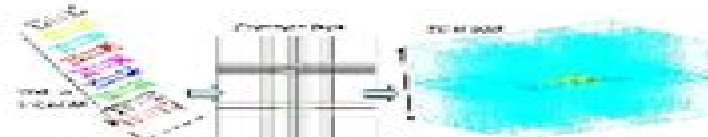


Fig. 2. 3D model construction.

are investigated. A 2D approach is defined and validated from a 3D one. Then, a full procedure is presented for AC copper losses computation taking into account SMPS waveforms. Finally, the validity of the approach from AC copper losses to thermal management is presented on an industrial full-bridge application.

II. MODELS

A. 3D Approach

Geometry complexity can be taken into account by numerical methods instead of analytical approaches [3]. Magnetic core, PCB corners and filling resin suppose that 3D approaches are required (Fig. 1). Geometry is built by a vertical projection of the layers on a common face. The resulting geometry is extruded (Fig. 2). 3D adaptive meshing is performed in order to accurately take into account frequency effects (Fig. 3). Unfortunately such models require too high time consuming and memory size. For example, the device presented in Fig. 1 (initial geometry) and modeled in Fig. 4 has required more than 3Go of RAM (allowable memory of usual computers) for meshing and solving steps. So, simplifying assumptions are necessary. The study is focused on a Finite Elements analysis of 2D/3D behavior linked to frequency effects.

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Numerical Modelling Of Eddy Currents

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