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ORIGINAL RESEARCH

Accurate design, simulation and implementation of AC/DC inductors for power electronic converters

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Abstract

This article proposes a holistic and improved methodology for the inductors' design in power electronic circuits operating at high frequencies. This methodology includes an analytical design, a finite element modeling of the electromagnetic behavior with JMAG software, a simulation analysis in a Simulink environment, and experimental verification of the effectiveness of inductor design in a laboratory-scale step-up boost power converter prototype. The holistic approach allowed us to achieve all target specifications such as maximum power (300 W), minimum voltage (60 V), inductance (1.77 mH), and maximum current ripple (1 A). It guarantees the losses' minimization in core and copper (21.47 W), and marginal errors below 4% between the analytical, simulated, and experimental values.

1 | INTRODUCTION

Power electronic converters are indispensable to achieve the energy conversion process in many applications such as full cells, battery energy storage systems, electric chargers, electric vehicles, solar generation, DC loads etc. [1–3]. In particular, DC-DC power converters are used in such applications to step up/down the DC voltage [1, 4], where magnetic inductors play a key role in regulating the output voltage since they smooth out the pulses thanks to their capability in storing and releasing energy and filter to generate stable output with the output capacitor. In this context, the topology of the step-up DC-DC boost converter in Figure 1 utilizes one high-frequency power device operating at a high switching frequency with minimum switching losses. After defining topology and power device, the inductor's design makes up a degree of freedom to optimize its performance [5].

1.1 | Literature review

According to the literature, conventional inductor design strategies are established according to their application such as filtering that is used in high-frequency power converters and pulse-width-modulators switched regulators, and regulation in AC system, existing two typical methods for designing based on the area product A_p or the geometric constant K_g [6–8]. The area–product approach is widely used to design inductors, especially when they undergo pulse width modulations (PWM) in DC-DC power electronic converters. It associates the geometrical core parameters with the magnetic and electric parameters. Meanwhile, the K_g approach uses the core geometry, allowing the estimation of core geometry for specific targets [9]. It does not consider the current density of the conductor, thus if the maximum current density is exceeded, a new iteration is executed until this criterion is fulfilled [10]. Both methodologies use