

Abstract

In high-frequency power electronic applications, power inductors often account for the majority of power losses, physical volume, and overall cost. Therefore, this research among other things addresses existing and proposes improved calculation and measurement techniques for the complex permeability and core power loss in ferrite-based magnetic components used in SMPSs. The new complex permeability measurement and calculation technique uses a series equivalent inductor model with a single fitting variable to closely reflect the physical behavior of the magnetic component and ensures accurate permeability estimation regardless of the inductor's size, geometry, winding configuration, or frequency range. The validation of the proposed model is performed both mathematically and through test-bench measurements. The results show that, if the inductor stray capacitor ESR loss tangent is correctly defined, then it is possible to obtain a relative fitting error of less than 2% across the entire frequency range. Based on complex permeability measurements, an enhanced inductor model is introduced, separating stray capacitance into winding- and core-related components, thereby improving AC loss modelling in SPICE based simulations. Regarding the core loss, a new core loss model dedicated to sinusoidal and rectangular AC voltages, called here an improved RESE (iRESE), is proposed. The iRESE extends the RESE by unifying the Steinmetz-based core loss model with the small-signal complex permeability model to comprehensively complete the entire core loss characteristics, regardless of the magnitude of the excitation signals, which was not previously possible. Moreover, it also considers the rectangular excitation of signals and the DC bias phenomenon commonly present in SMPSs, along with the magnetic permeability roll-off near the core saturation level and the influence of temperature changes. The model is structured to be modular, meaning that each part of it can be used separately according to the intended application. This is a unique approach that provides engineers and scientists with all the required information regarding core loss at once, as well as the flexibility to choose the approach depending on the application they are working on. The method was validated through test-bench measurements and includes error analysis to identify limitations in both simulation and measurement setups. The results show a very good agreement between measurements and fitting results. However, the up-to-date SPICE

simulation results are less precise due to the incomplete non-linear magnetizing current model, which is scheduled for future work. Although, developed for SMPSs, the approach is also applicable to other systems that use non-sinusoidal waveforms, such as electric vehicle inverters and wireless power systems.