Design Evaluation of Novel Integrated Magnetics

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Published
2014

Conference Title
IEEE International Magnetics Conference, INTERMAG Europe 2014

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http://www.intermagconference.com/2014/

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Abstract - A novel integrated magnetic transformer in vertical structure and a horizontal transformer, both are hosting the resonant tank for LLC resonant converters, are evaluated. The transformers have a power rating between 1 kW and 1.5 kW with an operating frequency of 75 kHz to 200 kHz depending on design and core material. To evaluate the performance of the introduced transformer, three prototype transformers including two novel structures and one conventional structure, have been fabricated. In comparison to conventional integrated structures a volume reduction of up to 50 % can be achieved. In order to analyse the models to each other, Finite Element Method (FEM) was employed to investigate the AC losses and current distribution in high frequency.

I. Introduction

LC resonant converters have attracted great interests in past decades due to the urge of increasing electrical power demand. However, the focus was set on the controlling circuit design [1], although a few researchers have achieved great successes on magnetic integration [2]-[8]. However, these structures suffer very often from the magnetic saturation, especially if a large Ls is required for the resonant tank design, or for example, with an extra inductor coil on the transformer which the leakage flux and main flux share the same magnetic path [9]. Therefore, a novel transformer is proposed which has the ability to deal with the early saturation issues.

II. Design Considerations and Construction

A) Top-up Transformer (conventional example)

The top-up transformer is composed with three FEE cores while two cores used as transformer and the top-up core acts as the add-on inductor. The structure is the sharing magnetic path between the transformer core and the inductor core. The adjustment of the Lp and the Ls is by controlling the air-gap distance in the centre leg of magnetic cores. The primary winding is composed with 2 bundles of 7-strands litz wire, whereas the secondary composed by copper sheets (Figure1a).

B) Magnetic Insertion Transformer (proposed structure)

In comparison, the proposed structure only requires two FEE core with two additional low permeability magnetic materials (Figure 1b). The adjustment of the Ls is now varied with the distance between the main core and
magnetic insertions. The primary is composed with 14 strands litz wire and the secondary is composed with copper sheets.

C) Horizontal Transformer

The horizontal IMC shown in figure 2 consist of a inductor and transformer in parallel configuration and a capacitor layer which goes throughout the both sections. Instead of liz wire, copper conductors on PCBs are used.

III. Measurement and test results

The frequency vs. efficiency simulation shows that the conventional integrated transformer can reach efficiency over 99% (prototype 3), whereas the novel top-up structure (prototype 2) reaches an efficiency of over 99.5%. The horizontal transformer reaches an efficiency of approximately 99%.

IV. Conclusions

Overall all transformers reach very high efficiencies of approximately 99% or higher. However, the novel transformer structure has the overall best performance.

V. References


Figure 1: a) conventional top-up structure, b) novel top-up structure, c) horizontal structure

Figure 2: Efficiency vs. Frequency