Winding Analysis of PCB Transformer in High Current, High Power Density Intermediate Bus Converter

A high current, high power density, top-cooling, unit-cell based LLC resonant converter with high modularity and scalability (as shown in Fig. 1) is used to cope with vertical power delivery for GPUs with expanded sizes and increased energy demands.

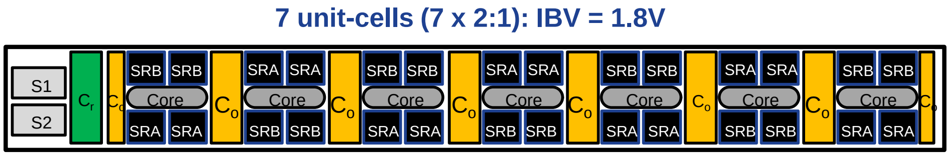

Fig.1. 7 unit-cells based 48 V-1.8 V IBV structure

For these low output voltage, high output current intermediate bus converter applications, the winding loss is crucial in affecting the entire converter's efficiency. Therefore, semi-serpentine primary winding (as shown in Fig. 2) with lowered twisting between the adjacent unit-cells such that reducing the current path length is used. Moreover, primary winding and secondary winding are fully symmetrical interleaved to optimize the winding ac resistance and ensure the current sharing between the parallel winding layers.

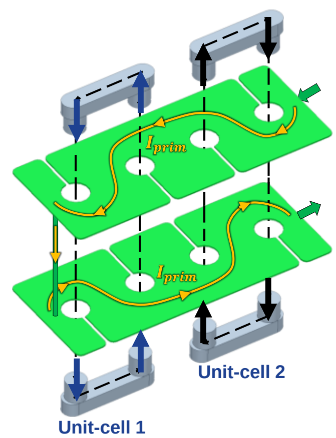

Fig. 2. Semi-serpentine winding

Based on FEA, the winding loss and leakage inductance are unbalanced within a switching cycle. Moreover, secondary currents tend to flow through layers closer to the top devices, and more primary currents are induced in the top layers. In this scenario, the effectiveness of the original parallel winding has been degraded.

To address the unbalanced winding performance, secondary windings (secondary A and secondary B, conducting in half-switching cycle) are arranged complementarily within a unit cell. Furthermore, several solutions are proposed to improve uneven current sharing. First, the primary winding connection was changed to ensure primary current sharing. Second, the primary layer was inserted between the top and secondary layers to damp the top device currents' pull effect. Third, different parallel winding sets were explored to optimize the effectiveness of parallel windings. With all these techniques implemented, the winding loss of the improved winding design was reduced by 12.7% when compared to the original winding loss.