Empowering Datacenters: Exploring Three-Phase LLC Converters for Efficient, High Power, and High Density Power Supplies

This study focuses on the relation between topology connection and the overall magnetic loss in three-phase LLC systems. The distinct advantage of three-phase LLCs over their single-phase counterparts lies in the degree of freedom in how magnetic elements can be connected. This flexibility necessitates a careful examination of the tradeoffs between core loss and winding loss for both the integrated transformer inductor (ITL) and pure transformer with separate inductor, a decision crucially influenced by the specific application requirements. Within the context of a datacenter employing a 400/48 V D2D characterized by a high output current at relatively low voltage, we scrutinize the performance of eight different topologies. The intricate relationship between core loss and winding loss becomes apparent when exploring Δ and Y connections. Assuming identical line current, Δ connection exhibits a 42% reduction in rms current and a 33% increase in volt-second compared to Y connection.

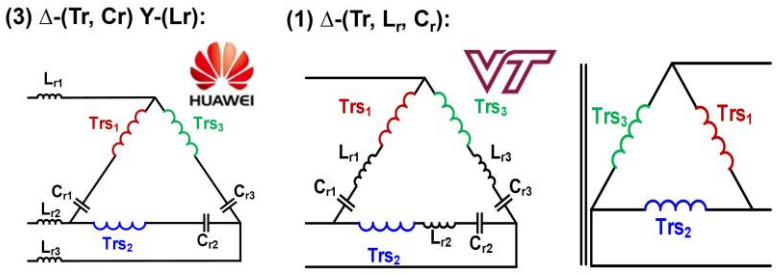

Fig. 1. Topologies 1 and 3 as candidates with Δ secondary

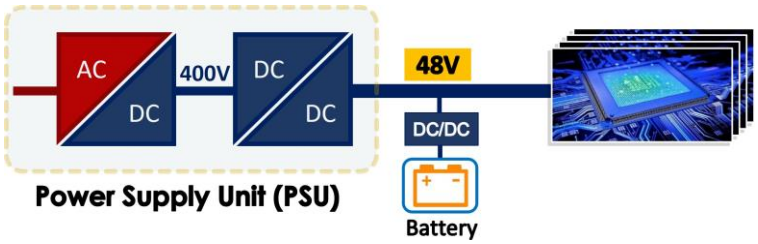

Fig. 2. 48 V bus architecture for datacenter power supply

Drawing comparisons to single-phase volt-second, Δ connection provides a 30% reduction, while Y connection achieves a 60% reduction. The primary hardware findings for three-phase LLC indicate a modest improvement in total magnetic loss due to misselection of topology. The Δ-based three-phase LLC simulation results achieve a remarkable 74% reduction in core loss with no reduction in winding loss, which presents a challenge giving the elevated power level of the converter and lack of regulation. These challenges emanate from the increased turns ratio in three-phase setups and the higher number of turns in the matrix configuration.

Addressing these challenges involves reassessment of the winding structure to leverage the inherently lower winding current in three-phase without compromising transformer size and integrating more leakage to meet hold-up time requirements. Despite these challenges, topology selection remains pivotal for three-phase LLC in datacenters. Topologies 1 and 3 emerge as preferred choices due to their low winding current, which aligns well with the demands of high-current applications. In conclusion, this study underscores the need for innovative solutions to enhance winding structures, integrate sufficient leakage, and carefully evaluate the suitability of ITL for high power applications, with ongoing efforts awaiting conclusive hardware results.