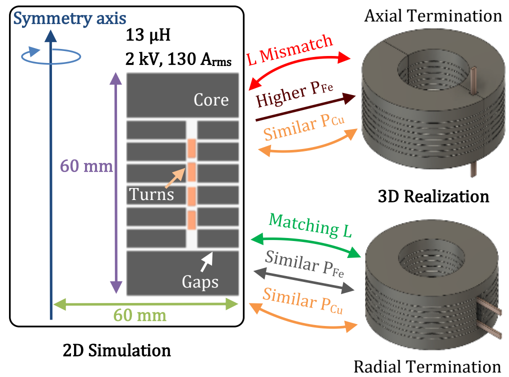
Inductor Realization for Substation Converters Absorbed into Lines for Electrical Distribution

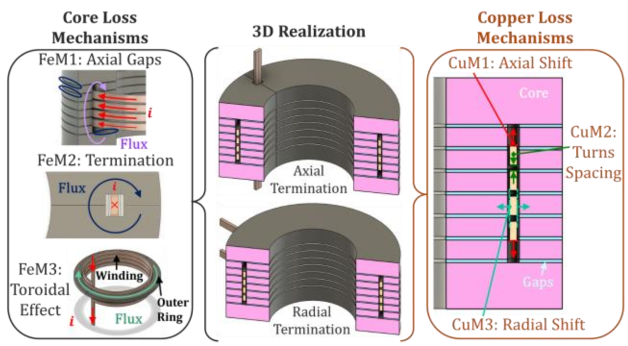
This work presents a study on the effects of the 3D realization choice of a 2D coaxial inductor design on its inductance and total loss. The inductor serves as the output filter of a high step-down, medium voltage (MV), high-power converter. The converter has a coaxial structure that mimics the shape of an MV cable. This enables a seamless connection to MV cables for different applications, such as grid connections for renewables and datacenters. The converter's coaxial shape requires most main components within, such as the output inductor, to be axial.

Taking advantage of the axial shape of the structure, the design space is most easily explored by considering a cross section of the inductor around an axis of symmetry, as shown in the left half of Fig. 1 (a). However, this approach assumes perfect axial symmetry; it does not consider 3D effects caused by the realization of the cross section design, such as the spiraling of the winding and the terminations connection like that seen in the right half of Fig. 1 (a). Investigating the axially terminated structure of Fig. 1 using FEA simulations revealed six mechanisms that cause the 3D structure to have a higher inductance and loss from the 2D design, as illustrated in Fig. 1 (b). These mechanisms depend on the core geometry and winding realization as well as prototyping tolerances.

Quantifying the effects these mechanisms can have on the inductor losses is important, as they can be very large. For example, Fig. 2 shows that the copper mechanisms' combined effects can cause the total loss to be 3x higher than the optimized design; a severe increase that has multiple negative consequences on the converter's thermal management system and efficiency.



(a)



(b)

Fig.1.(a) Two ways to realize the 2D design and the observed differences in inductance and losses (b) Six mechanisms that effect the total inductor loss based on the chosen 3D realization: three core and three copper mechanisms

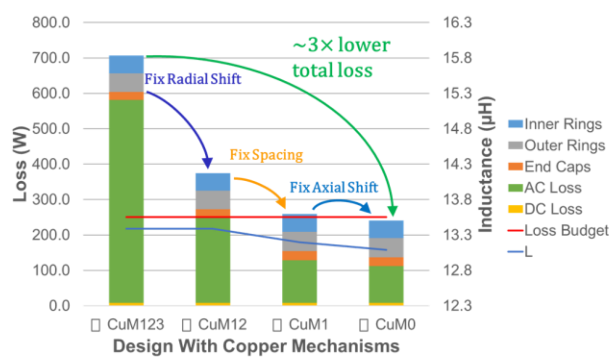


Fig. 2. Simulated total output inductor loss with the presence of different copper mechanisms. Starting from the left, all three mechanisms are present in the structure, denoted by "CuM123." They are then eliminated one at a time down to "CuM0," for which all mechanisms are eliminated. A factor of ~3x is observed between the two extremes