Modular Coaxial Power Converter for High-density Integration into Medium Voltage Cables

This work proposes combining the functionality benefits of power electronics with the power density benefits of high voltage (HV) cables to create a streamlined, high density power electronics solution that seamlessly integrates with medium voltage (MV) cables as shown in Fig. 1. Located at the ends of a medium or high voltage line, the proposed converter uses a cascade of coaxial power conversion cells to gradually step down the voltage, achieving an overall step-down ratio of >20:1. By mimicking the coaxial geometry of HV cables, the converter preserves the axisymmetric electric field of the cable that, when combined with a solid insulating dielectric, provides a significant density and voltage scaling advantage over conventional planar and PCB-based converter solutions. The scalability of the modular structure, in combination with the integration benefits, provide a flexible power electronics system that can adapt to the evolving demands of the grid.

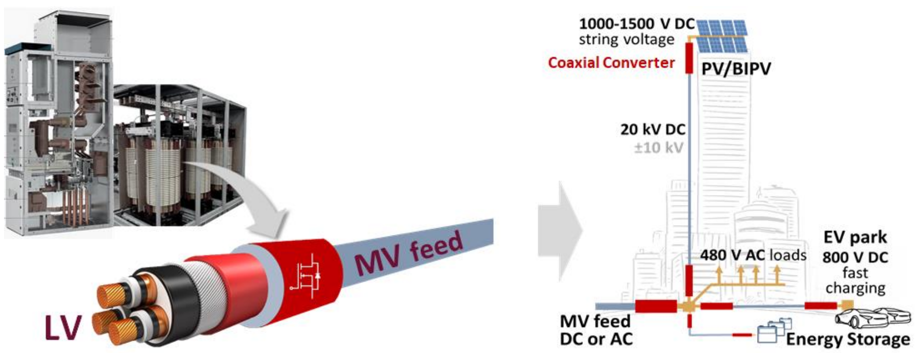

Fig.1. Concept of operation for a cable-integrated power converter that mimics the coaxial structure of MV cables to achieve high power density while leveraging modern power electronics to achieve high efficiency.

Similar to MV cables, the converter is fully passively cooled. The passive cooling strategy allows for combined installation with existing MV cable systems without the added cost, maintenance needs, infrastructure, and reliability concerns associated with active cooling systems. Passive cooling is achieved by distributing the lossy components along the length of the cable, lowering the loss per length of the system. Fig. 2 shows a 3D rendering of a 50 kW, 10 kV power conversion cell, along with the coaxial component prototypes. Each component is custom designed to preserve the coaxial formfactor of the cell, minimizing disruptions to the internal electric field. Heat pipes are used throughout the cell to transfer heat axially, uniformly distributing heat to the radial fin structure along the outside of the cell. The fin structure is optimized for passive heat rejection to air from within an underground cable vault. In an installation, cells can be cascaded axially to increase power delivery without affecting the loss per length.

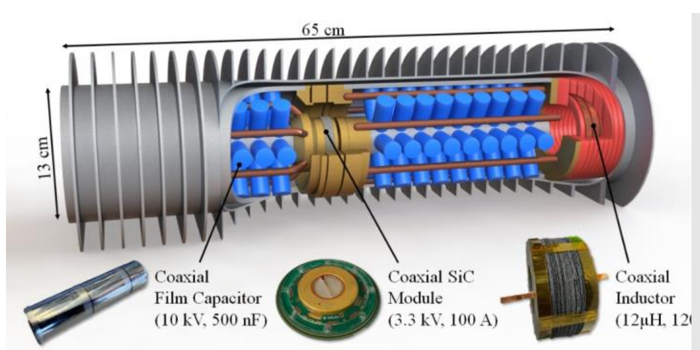

Fig. 2. 3D design of 10kV-capable, 50 kW, cell with hardware prototypes of the custom coaxial capacitor, SiC MOSEFT module, and inductor. Cell is shown with external radial cooing fins designed to improve passive heat rejection.