Insulation Coordination of a 22 kV DC to 13.8 kV AC, 1.1 MVA 3-phase 7-level Flying Capacitor Converter

The recent development of 10 kV SiC MOSFETs enable the high power density design of medium voltage converters. One of the enabled topologies is the flying capacitor converter (FCC). Utilizing the higher blocking voltage of the 10 kV SiC MOSFETs, a 7-level FCC is developed in concept and demonstrated in a prototype. As a result of increased voltage levels in compact spaces, the presence of high electric field intensities throughout the converter requires deliberate considerations in insulation design and layout coordination. Without insulation coordination, partial discharge (PD) and full breakdown could occur in the system, leading to rapid insulation degradation, along with possible faults and EMI propagation. In addition, following an analytical approach to the solutions instead of standard guidelines allows for higher density of the converter.

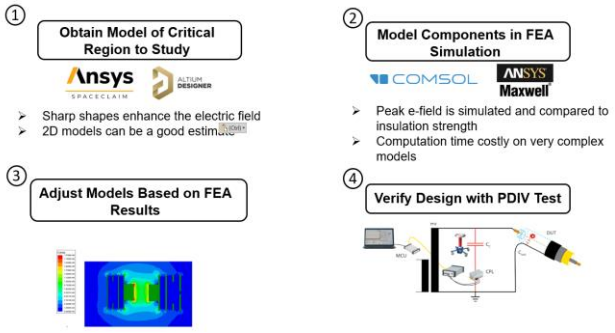

Fig. 1. Step-by-step process for designing a PD-free system

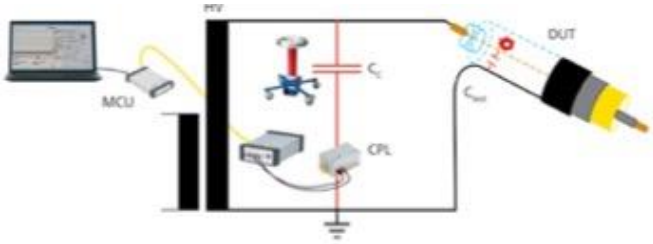

Fig. 2. Omicron MPD 600 PD detection scheme

Fig. 1 shows the overall design steps taken to achieve PD-free operation for a high voltage converter. Designing a partial discharge free operational converter requires insight into the peak e-field intensities present. First, critical e-field areas within the converter are identified for study. This criterion is based on (1) amplitude of differential voltages, (2) distance from one potential to another, (3) shape of the conductors, (4) presence of triple point interface. An increase in differential voltage amplitude, decrease in distance, presence of a sharp interface, and triple point all enhance the electric field.

Finite element analysis (FEA) simulations are completed on models of the critical e-field regions. Voltage differential levels defined by the converter operation are applied, and the appropriate distance and e-field mitigation techniques are applied based on the peak dielectric strength of the insulation material. Based on the results of FEA simulations, the model is adjusted to meet insulation requirements. Techniques can be separated into two main categories: geometric or material solutions. Solutions are verified by partial discharge testing using a coupling capacitor to generate apparent charges in phase with the excitation voltage. The setup for PD detection is shown in Fig. 2.