Transient Voltage Suppression (TVS) Diode-based Protection for 10 kV SiC MOSFET in 3-phase 7-level 1.1 MVA, 13.8 kVac, 22 kVdc Multicell Power Converter

The operation and failure modes of the flying capacitor multilevel converter topology are well known and the protections for Si IGBT-based converters are well established. However, when it comes to high voltage SiC MOSFET-based converters, there are some particularities that must be evaluated: shorter energy withstanding time, higher dv/dt, and higher insulation stress. For that reason, a re-assessment of the failure modes for a 7-level 13.8 kV, AC 22 kV, DC 1.1 MVA, 3-phase flying capacitor converter using 10 kV SiC MOSFETs was conducted. A fault propagation mechanism between cells was identified when both switches of the same cell fails, a so-called cell short-circuit fault (CSCF). To prevent the switches from the surrounding cells from being damaged, a protection module based on passive protection using a transient voltage supression (TVS) diode was designed.

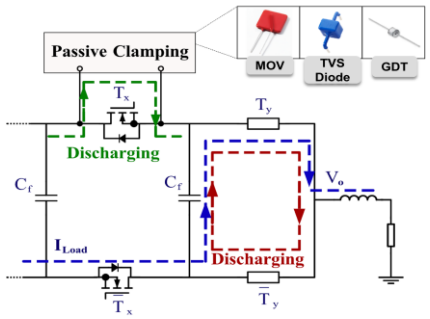

Fig. 1. Passive clamping proposed

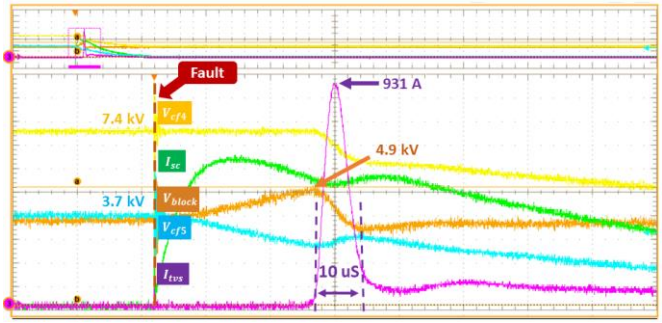

Fig. 2. Test waveform at rated cell voltage 3.7 kV, showing V_{cfleft} (yellow), $V_{cfright}$ (blue), I_{tvs} (purple), I_{sc} (green)

Fig. 1 shows the protection module operation fundamentals when CSCF occurs at the cell closest to the AC terminals. The short-circuit current discharges the flying capacitor in the faulty cell, which increases the voltage stress on the surrounding cell. To limit overvoltage stress and avoid a second failure, a clamping passive circuit based on a high energy capability TVS diode is inserted in parallel with the switches. The TVS diode current discharges the capacitor on the left side and maintains the cell voltage under safe values. Also, no energy is dissipated on the healthy switches, which prevents failure propagation due to thermal runaway. Fig. 2 shows the results of an experiment conducted to verify the protection efficiency. When the cell voltage reaches the TVS-diode breakdown threshold (4.4 kV), a fast current spike (in purple) discharges the capacitor on the left, maintaining the voltage at the surrounding cell switch lower than 5 kV.