

## Multi-functional High-voltage DC (HVDC) Converter

The high-voltage dc (HVDC) industry has been witnessing a shift from line commutated converter (LCC) based systems to voltage source converter (VSC) based systems, and the modular multilevel converter (MMC) has further revolutionized the HVDC industry by significantly enhancing power quality, efficiency, and controllability, making it the predominant choice. However, the wide adoption of HVDC is hindered by challenges, notably those related to system stability concerns and fault management issues.

This paper introduces a novel multi-functional HVDC converter, as illustrated in Fig.1. By replacing a small fraction (10-15%) of submodules in traditional MMC – transitioning from Si-based half bridges to fast-switching SiC-based full bridges – the converter is equipped to inject superimposed voltages in a wide frequency spectrum into the traditional MMC output. This modification enables three functions: 1) in-situ online impedance measurement for stability analysis, 2) active filtering and active damping to mitigate the resonance and oscillations, and 3) enhanced fault current protection to ensure safe operation.

The impedance measurement is conducted in  $dq$  frame, as outlined in Equation (1). The fast-switching SiC full-bridge submodules are strategically controlled to inject voltages into the system, enabling the real-time calculations and monitoring of both ac and dc side impedances utilizing the sensed voltage and current signals. Subsequently, the stability analysis based on the generalized Nyquist criteria (GNC) is performed given the impedance data, thereby ensuring robust operation and preventing harmonic resonances. Simulations performed in PLECS indicate that this method accurately measures the impedance on both sides of the converter.

The active damping function is facilitated by configuring SiC full-bridge submodules to mimic a virtual impedance to actively dampen the detected resonance before it escalates, thereby ensuring system stability. Additionally, the SiC submodules are capable of injecting a negative voltage at the beginning of a fault to quickly and effectively suppress its development. Demonstrations via simulation are provided for each of the functions stated above.

This paper presents a novel multi-functional high-voltage dc converter that incorporates three critical functions with minimal modification to the existing design, where SiC full-bridges can be designed as convenient replacements for redundant submodules installed in existing MMC. This innovation holds considerable promise for practical industrial application, due to its efficient integration of enhanced features with minimal structural changes.

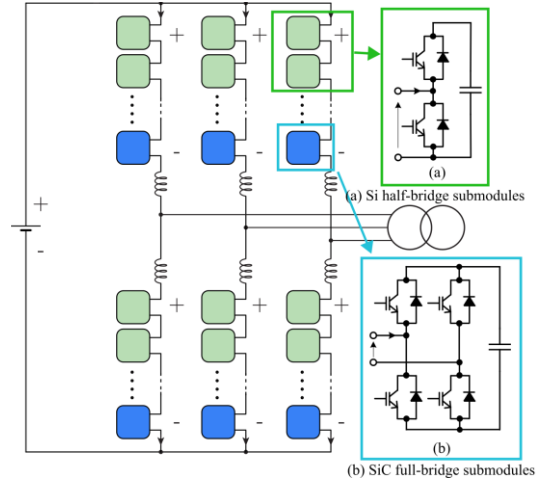


Fig. 1. Multi-functional intelligent HVDC converter topology

$$Z_{dq} = \begin{bmatrix} \tilde{v}_{d1}(s) & \tilde{v}_{d2}(s) \\ \tilde{v}_{q1}(s) & \tilde{v}_{q2}(s) \end{bmatrix} \begin{bmatrix} \tilde{i}_{d1}(s) & \tilde{i}_{d2}(s) \\ \tilde{i}_{q1}(s) & \tilde{i}_{q2}(s) \end{bmatrix}^{-1} \quad (1)$$