Topology and Control of High-Resolution Multilevel Inverter for Renewable Energy Application

Abstract: Power converters are playing a significant role in achieving sustainability, flexibility, and efficiency goals in the current utility systems. Multilevel converters for medium-voltage and high-power applications have gained significant acceptance because of their merits, such as lower harmonic generation and improved efficiency compared to conventional two-level converters. Asymmetric converters based on high-resolution converters can generate high-resolution voltage waveforms with a limited number of isolated supplies and semiconductor devices. This also reduces the switching losses and optimizes conduction losses. Enabling a selected multilevel converter topology for a particular application requires source and load matching, and it should address the challenges associated with the application to ensure proper operation. This thesis investigates an asymmetric multilevel inverter for medium-voltage, high-power applications. The dc-link voltages have an asymmetry ratio of 16:4:1, enabling the inverter to generate a high-resolution voltage waveform. This work proposes solutions for implementing the asymmetric multilevel inverter for isolated and grid-connected PV applications. The work explores its application in offline UPS systems by reducing device switching frequency, increasing the number of levels with the same number of devices, and introducing a battery optimization strategy for improved efficiency. For STATCOM applications, floating capacitor balancing and reactive power control are addressed using an auxiliary circuit and d-q control, resulting in higher power injection capability with minimal auxiliary bridge power requirements. The high-resolution voltage levels of the inverter are also shown to be suitable for active power filter applications, fulfilling current injection requirements at the point of common coupling through effective reference generation, tracking, and dc-link balancing strategies. Finally, the topology is investigated for grid-connected PV systems, where a single dc-source configuration is realized using isolation transformers, with low power handled by the auxiliary bridges. All proposed solutions are validated through MATLAB/Simulink simulations and experimental verification using a hardware prototype built with the TI Launchpad F28379D DSP. The inverter's low switching frequency enables the generation of gating signals using general-purpose I/O pins, eliminating the need for dedicated EPWM modules.

Keywords: Active power filter, asymmetric inverters, hexagonal decomposition, nearest space vector modulation, solar PV inverters, STATCOM, UPS.