EXPLORING MODULAR MULTILEVEL CONVERTER FOR RENEWABLE ENERGY APPLICATIONS

Abstract: The rapid penetration of renewable energy and the electrification of transportation demand power electronic systems that are efficient, modular, scalable, and grid-friendly. Traditional two-level converters face limitations at higher power and voltage levels due to bulky filters, increased switching losses, and limited fault tolerance. In this context, multilevel converters, with their modular structure, high-quality waveform generation, and inherent redundancy, emerge as a promising platform for next-generation energy systems.

This thesis investigates multilevel converter-based solutions across three interconnected domains. The first part presents a modular dc–dc converter derived from cascaded half-bridge submodules. The topology minimizes passive component requirements, achieves stable operation at high duty ratios, and inherently balances distributed storage units. Simulation results validate its compact design, high efficiency, and adaptability for dc microgrid and storage integration.

The second part develops a battery-integrated modular multilevel converter (MMC) inverter for photovoltaic (PV) systems. By embedding batteries at the submodule level, the converter enables distributed storage management, state-of-charge (SoC) equalization, and seamless bidirectional energy flow between PV, storage, and grid. Both simulation and experimental validation confirm low-distortion grid currents, high efficiency at low switching frequencies, and stable operation under dynamic conditions.

The third part proposes a multilevel converter-based charging station for electric bus fleets. A cascaded H-bridge (CHB) rectifier ensures clean grid interfacing with multiple isolated dc outputs, while MMC-based on-board chargers (OBCs) within each bus handle both charging and propulsion. Simulation studies demonstrate balanced battery charging, reduced ripple, near-unity power factor, and the capability to supply ancillary services to the grid.

The findings collectively establish that modular and multilevel converter architectures are well-suited for high-power applications where efficiency, reliability, and flexibility are essential. Beyond addressing current challenges, the proposed systems pave the way for integration with renewable sources, smart grids, and vehicle-to-grid (V2G) technologies. The research concludes that CHB and MMC topologies can form the backbone of future sustainable infrastructures, enabling large-scale electrified mobility and net-zero energy systems.

Key Words: - Electric Vehicle Charging Station, Grid-Connected Inverters, Modular dc-dc Converter, Modular Multilevel Converter, Photovoltaic Solar Inverter.