

Abstract

The increasing demand for high-efficiency and compact power conversion systems in electric vehicle (EV) infrastructure and renewable energy integration has driven the exploration of high-frequency isolated DC-DC and DC-AC converter topologies. This thesis presents modulation for bidirectional DC-DC and DC-AC (1-phase and 3-phase) phase modulated converters with step voltage switching (SVS) for device voltage shoot mitigation without using any clamp/snubber circuit. Voltage overshoot is a critical reliability concern in phase modulated converters. The voltage overshoot across the devices in phase modulated converters are due to transformer leakage inductance and abrupt switching transitions. The SVS technique leverage step-wise voltage transitions and tailored switching sequences to mitigate the voltage overshoot at its origin. First, modulation scheme for a phase modulated bidirectional DC-DC converter topology with step voltage switching is developed, ensuring voltage overshoot mitigation (without clamp/snubber circuits) through out the converter operation. Detailed soft-switching analysis, and hardware validation are also carried out to confirm performance benefits over existing solutions for voltage overshoot suppression. Second, this modulation is extended to a phase modulated bidirectional 1-phase AC-DC converter by essentially retaining all the benefits like, soft switching, voltage overshoot mitigation without clamp circuits, better efficiency etc. Third, a novel reduced switching state PWM (RSS-PWM) strategy is introduced for 3-phase AC-DC phase modulated converters to reduce the number of switching transitions per cycle, effectively lowering switching losses and minimizing the occurrence of voltage overshoot per switching cycle. Then SVS is implemented to achieve complete voltage overshoot mitigation across all operating modes. Simulation and experimental results on laboratory-scale prototypes validate the proposed methods, demonstrating significant improvements in voltage overshoot mitigation without clamp circuits, switching loss reduction, and efficiency enhancement.

