On the Integration of Wide Band-gap Semiconductors in Single Phase Boost PFC Converters - DTU Orbit (09/11/2017)

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Power semiconductor technology has dominated the evolution of switched mode power supplies (SMPS). Advances in silicon (Si) technology, as the introduction of metal oxide field effect transistor (MOSFET), isolated gate bipolar transistors (IGBT), superjunction vertical structures and Schottky diodes, or the introduction of silicon carbide (SiC) diodes, provided large steps in miniaturization and efficiency improvement of switched mode power converters. Gallium nitride (GaN) and SiC semiconductor devices have already been around for some years. The first one proliferated due to the necessity of high frequency operation in optoelectronics applications. On the other hand, Schottky SiC power diodes were introduced in 2001 as an alternative to eliminate reverse recovery issues in Si rectifiers. Wide band-gap semiconductors offer an increased electrical field strength and electron mobility compared to Si semiconductors. Moreover, both semiconductor materials are particularly interesting for high temperature operation. These characteristics makes integration of SiC and GaN devices as the next logical step to further increase efficiency and power density in SMPS. This work is part of the PhD project “Single phase PFC converter using wide band-gap devices” and focuses on attainable advantages by introducing wide band-gap semiconductors, and more particularly GaN devices in power factor correction circuits (PFC). First, an overview of current state-of-the-art semiconductor technology in the 600/650 V range, and recent developments on the integration of GaN devices in SMPS are provided. The second part of the thesis provides an insight on semiconductor characterization and compares state-of-the-art Si technology to current available GaN switches. After this overview, a comparison between continuous (CCM) and boundary conduction modes (BCM) in PFC applications is provided based on the semiconductor characterization data. The comparison takes into consideration the electro magnetic interference (EMI) filter size and the converter input inductor volume, as a necessary part for evaluating the converter efficiency and power density. The last part of the thesis provides technical aspects on the controllability of GaN switches in high switching frequency implementations. Moreover, a zero voltage switching (ZVS) control scheme for BCM implementations, capable of operating in the MHz switching frequency range is presented.

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