Contribution ID: **162** Type: **Oral Presentation**

The Benefits of Using Cascode GaN Power Devices in a DC-DC Bidirectional Buck-Boost Converter

Wednesday 6 June 2018 11:00 (15 minutes)

Due to global concerns over climate change and the depletion of fossil fuels, the worldwide interest in renewable energy sources, such as photovoltaic (PV) and wind, is increased significantly for electricity generation. Grid-connected PV and wind energy conversion systems with battery energy storage are considered to be the fastest developing clean energy technologies because of their increased power capacity and improved efficiency. These systems commonly employ DC-DC bidirectional buck-boost converters, which play a vital role in controlling, storing, and transferring electrical energy between two sources in both directions. However, these converters suffer from large semiconductor loses in silicon (Si) power devices, which are operationally limited due to their intrinsic material properties. Wide bandgap (WBG) power devices, especially gallium nitride (GaN), provide superior advantages with their tremendous operating capabilities and reduced conduction and switching losses. The benefit of replacing all Si devices in a bidirectional buck-boost converter with GaN devices is not well-defined. The main objective of this paper is to investigate the impact of using cascode GaN-FET devices on the converter's switching performance and energy efficiency. Si-based and GaN-based converters are designed and compared under identical operating conditions of blocking voltages, switching frequencies, and working temperatures to evaluate the converter performance. The switching behavior of the Si and GaN devices is examined through the double-pulse test (DPT), taking different gate resistance values and switch currents into account. The total power loss in the two converters is computed to determine their efficiency over a wide range of switching speeds, input voltages, and output power levels. The outcomes reveal considerable benefits of emerging GaN semiconductor technology in the bidirectional buck-boost converter, leading to significant improvements in switching performance and energy efficiency.

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Session Classification: Oral 10 - Power Electronics

Track Classification: Power Electronics, Power Supplies, Prime Power, Rotating Machines, and Energy Converters