Control and Design Aspects of Components and Systems in High-Voltage Converters for Industrial Applications

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Abstract

High-frequency dc-dc converters are widely used in power electronic applications, both in consumer products and industrial products. By operating the converter at higher frequencies both a smaller size and better control characteristics can be obtained.

It is the objective of this work to investigate how high-frequency power converters can be optimized for high-voltage industrial applications. Specifically, power supplies for electrostatic precipitators (ESP) are considered. The work refers to operating frequencies higher than 20 kHz and load voltages reaching 100 kV and above. The power handling capability ranges from 10 to 200 kW.

High-frequency power supplies were originally introduced on the ESP market in 1993. An evaluation of the experiences gained during the first decade of operation is presented. It was found that the dust emissions have been reduced at the majority of the installations.

Efficiency aspects like IGBT losses in soft-switching operation with a sinusoidal collector current and the influence of different control methods have been analyzed. Dynamic properties of the IGBT such as: dynamic conduction losses and dynamic tail charges are presented and experimentally verified. The IGBT losses have been evaluated for LCC-converters operating above the resonance frequency. The losses have been measured and compared for different control methods and for different turn-off strategies, zero-current-switching and zero-voltage-switching, respectively. It is shown experimentally that the LCC-converter is more efficient than the series-loaded resonant converter for a range of values of the parallel capacitance. This is because the LCC-converter allows a lower turns ratio of the transformer.

The high-voltage high-frequency transformer has been analysed with respect to its parasitic elements. A method is presented, integrated rectification, which enables a sub-division of the winding capacitance into an AC-part and a DC-part. It is validated experimentally that they may be utilized as circuit elements and that the ratio of these capacitances may be varied within a wide range. This method is considered to be of importance when optimizing converters utilizing topologies where the output rectifier is followed by a capacitive filter.

Keywords
High-voltage converter, resonant converter, high-voltage transformer, transformer parasitics, IGBT, soft-switching, control