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Functional Integrated Electronics for HV Architectures

- From today's dedicated electronics to multifunctional power supplies in electric vehicles -

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Cost, volume, and efficiency improvement for power electronics in electric vehicles is a major challenge. The high voltage (HV) architecture of electric vehicles is changing from past distributed architectures with one box per function, to today's cluster architecture with battery, HV box, and axle drive as main components. In order to reduce cost and volume, integration will continue towards a centralized modular architecture. For this centralized electronics, we present a multifunctional power supply converter that is capable to replace all galvanic connected functions. It provides an inverter with inherent boost function, bidirectional charger for AC and DC including DC boost and an external power take-off for electrical consumers. To switch between these functionalities, three identical phase modules of the converter are multiplexed via relays to the different functions, which are listed in Fig. 1 in more detail. These relays are integrated in a so called interface box.

Key feature of the converter is a true sinusoidal output voltage, which in turn results in approximately zero harmonics and very low noise in the electric machine, or a DC output voltage that can be freely configured. Also any other voltage signal shape can be created. To modulate dynamically the analog voltage of the output capacitor, two half bridges connected via an inductor are used. The half bridges use SiC MOSFETs with a switching frequency of up to 500 kHz. The load is driven by the voltage difference of at least two output capacitors. The parasitic effects in the circuit were reduced by a power module PCB design with very low impedance.

For the reduction of the well-known high-switching losses inside the 1200 V SiC MOSFETs, a soft switching control has been implemented. Due to the high-switching frequencies, one challenge in controlling the multifunctional converter is the short closed-loop controlling times, which make it necessary to use Field Programmable Gate Array (FPGA) technology. A performance real-time machine comprising a CPU, as well as the FPGA equipped with fast I/O modules, has been chosen as controller platform. This enables deployment of behavioral logic and slower tasks, like torque and speed control on CPU; whereas fast tasks, like inductor current control or Pulse Width Modulation (PWM) actuation are implemented on the FPGA.

In order to prove the concept and to support the design phase, dynamic and losses simulations were carried out. In driving simulation, WLTC with a C-segment battery electric vehicle of 1700 kg weight and a cW-coefficient of 0.28 was considered, in which an average cycle efficiency of ~95 % was achieved. Optimization analyses are ongoing to further decrease the switching losses and optimize the efficiency over the whole operating range of the electric machine. For DC charging, active power ranges from 50 kW to approximately 500 kW were examined. The charging efficiencies vary between 97.2 % and 98.1 %.

For 11 kW AC charging, the efficiency of the new converter was compared with the standard two-stage, on-board charger (OBC) over the voltage range of an 800 V battery. The efficiency of the novel multifunctional converter outperforms the standard OBC over the whole battery operating voltage level by approximately 2 %.

The multifunctional converter is capable of producing freely adjustable output voltage signals with bidirectional signal flow and signal conversion capabilities, making it a promising solution to improve cost, volume and efficiency of the HV system. Remaining important challenges are the HV safety for galvanic connected charging and the complexity of the power stage.

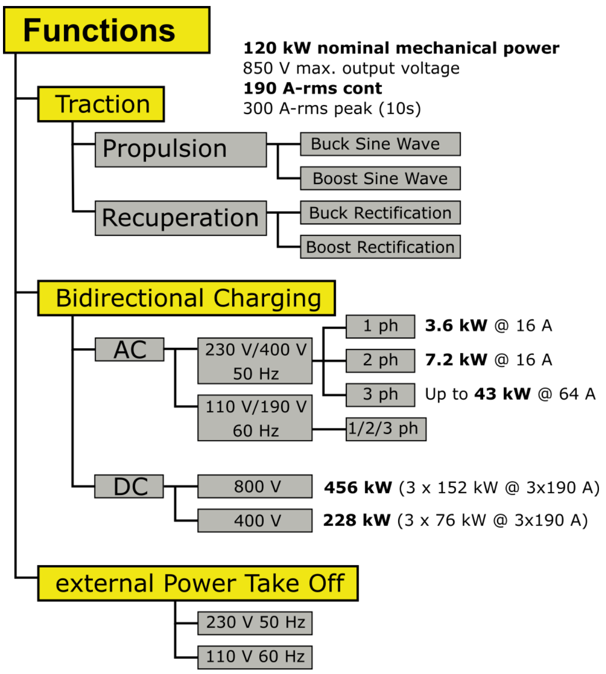

Fig. 1: Functional overview of the converter