ABSTRACT

SYMPOSIUM POWER ELECTRONICS FOR ENERGY TRANSITION

30 Sept. & 1 Oct. 2025

Graz, Austria

Submission to the Call for Presentations and Posters

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Corresponding topic (please tick)	☒ Power Electronics in Automotive & Charging Applications ☐ Power Electronics in Medium Voltage Applications ☐ DC Industry ☐ Sustainability & Circular Economy in Power Electronics
Proposed presentation title (you can indicate a preference for oral or poster presentation in the submission form)	Design and Implementation of a 3 kW All-SiC Current Source Inverter
Authors (please highlight corresponding author / speaker)	Benedikt Riegler (corresponding author), Michael Hartmann

Abstract:
The design, optimization, and implementation of a high-efficiency 3 kW current source inverter (CSI) using silicon carbide (SiC) power semiconductors is demonstrated, with a focus on achieving high power density.

The presented design methodology integrates both analytical and numerical techniques to optimize the inverters passive components, including filter capacitors and the DC-link inductor, power semiconductor devices and the integrated thermal management system ensuring high efficiency and a compact design. The optimization process leverages semi-analytical loss models, specifically designed for the most advanced modulation strategy, providing accurate predictions of power semiconductor conduction and switching losses and DC-link inductor losses.

Figure 1 displays the basic structure of the investigated three-phase CSI supplied by a buck-stage from a DC voltage source. The DC-link inductor is split between the positive and negative DC-rails and serves as the primary energy storage element. By appropriately controlling the buck-stage, a constant DC-link current is maintained. Using pulse-width modulation (PWM) in the inverter stage, this current is then shaped into arbitrary three-phase current waveforms at the load. The output capacitors are required for basic operation and filter the output voltage, thus eliminating the need for additional output filters in this topology.

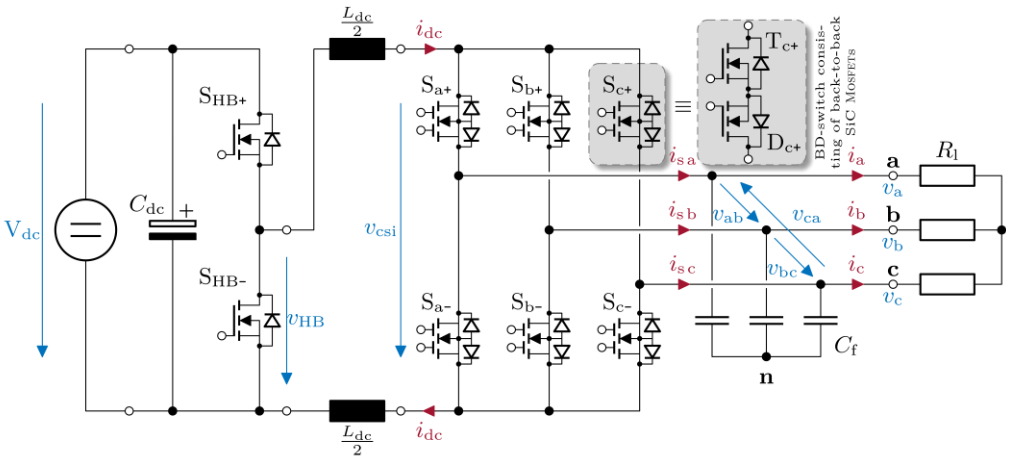
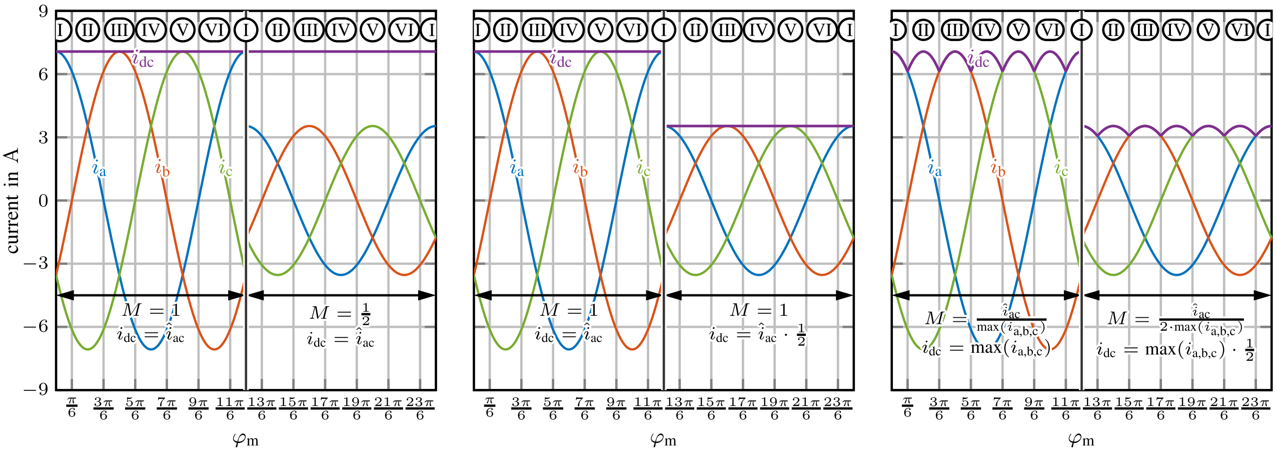


Figure 1: Basic circuit diagram of the designed CSI with a buck-stage input connected to a three-phase resistive load. The reverse-blocking semiconductor switches are built from SiC MOSFETs arranged in a back-to-back (common source) configuration, and the DC-link inductor is split between the positive and negative rails.

The addition of the input buck stage provides flexibility in changing the DC-link current magnitude and modulation index, resulting in three meaningful operating modes for the whole converter. While for two operating modes either the DC-link current or the modulation index is kept constant in the third operating mode a 2/3 PWM approach is chosen. These three operating modes are analyzed in detail and are validated through experimental tests.



(a) (b) (c)

Figure 2: Idealized curves of the three-phase output current with a load step from maximum current to half of the maximum current. ***(a)*** *Operating mode 1: DC-link current is constant and current amplitude is adjusted using modulation index.* ***(b)*** *Operating mode 2: DC-link current is adjusted accordingly and modulation index is kept constant.* ***(c)*** *Operating mode 3 2/3 PWM modulation.*

Based on the design and optimization process, a 3 kW three-phase CSI prototype was developed. A picture of the prototype is presented in Figure 2. It is capable of operating at a switching frequency of 100 kHz at an input voltage of up to 500 V outputting a maximum RMS AC voltage of 200 V and has been extensively tested to validate the theoretical framework developed. The prototype demonstrates a high volumetric power density of 4.5 kW/L and achieves a peak efficiency of over 98 %. As can be seen from Figure 3, the experimental results closely match the theoretical predictions for semiconductor switching and conduction losses, inductor core and AC and DC copper losses, showcasing the effectiveness of the presented design process. Detailed analysis of switching behaviors and loss mechanisms confirmed the advantages of SiC technology, especially in terms of reduced thermal stress and enhanced switching performance.

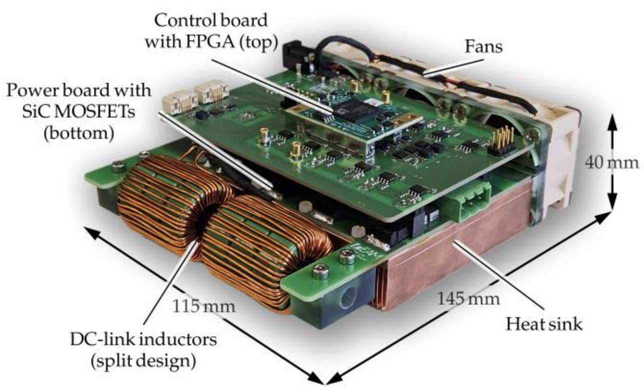


Figure 3: Prototype of the implemented buck-CSI system showcasing a compact, stacked two-board design with an integrated thermal management system and two (split) DC-link inductors.

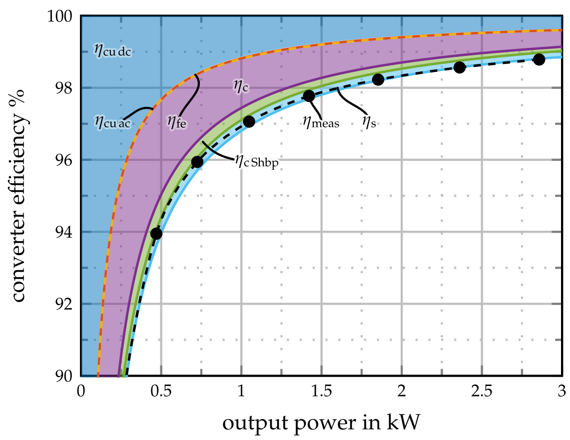


Figure 3: Measured efficiency curve (black dots, HIOKI PW8001) of the implemented inverter stage at different modulation indices resulting in different AC output powers at a DC-link current of 7 A and switching frequency of 100 kHz.

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Contact details of corresponding author / speaker	Title	
	First name	Benedikt
	Last name	Riegler
	Organisation	Graz University of Technology
	Department	Electric Drives and Power Electronic Systems Institute
	Position	University Assistant
	Address	Inffeldgasse 18, 8010 Graz
	Email	benedikt.riegler@tugraz.at
	Phone	+43 316 873 7740

Short CV	Benedikt Riegler received the B.Sc. and Dipl.-Ing. degrees in electrical engineering from Graz University of Technology, Graz, Austria, in 2017 and 2019, respectively. He is currently working as a PhD student at the Electric Drives and Machines Institute, Graz University of Technology. His research interests include the design of three-phase inverter systems for electric drives and high bandwidth current measurement in power electronic applications.
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