SCIENCE ▪ PASSION ▪ TECHNOLOGY

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A Novel Test Method for Switching Loss Measurement of Reverse-Blocking Semiconductor Switches in Current-Source Inverters

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Motivation

- Challenges posed by WBG switches: high $\frac{dv}{dt}$ causes isolation stress, losses, EMI, bearing currents, overvoltages with long cable runs, ...
- Possible solution: **current-source converter** (CSC).

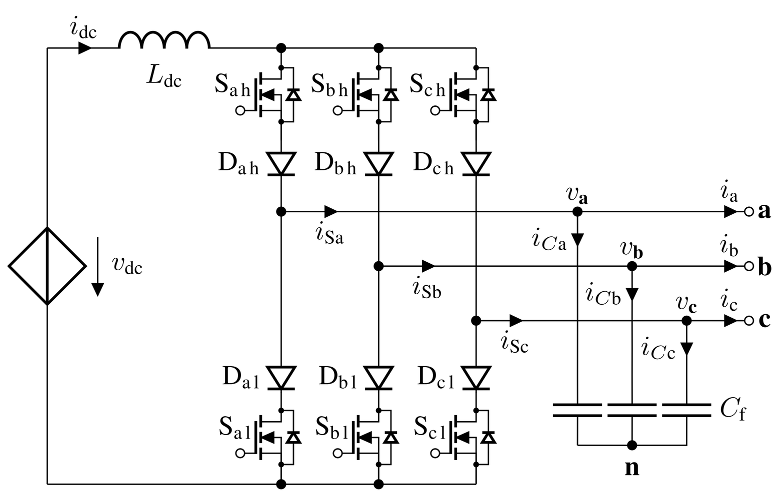

Fig. 1: Basic circuit diagram of the inverter side of a current-source converter. Here, the reverse-blocking semiconductor switches are constructed from MOSFETs and diodes.

- **DC-link inductor** imprints a constant current.
- Smooth output waveforms due to inherent **second order filtering** (L_{dc} + C_f).
- Big drawback: reverse voltage blocking (RVB) switches necessary! Possibility for use of Bidirectional (BD) GaN Switches.

Switching Loss Characterisation

- Switching loss measurement different from VSI → special **commutation cell** and **double-pulse test** (DPT) needed.
- The proposed cell represents the three upper (or lower) RVB switches of the CSI.
- **Voltage source** for magnetizing the **DC-link inductor** and applying commutation voltage.
- **Resistor** for demagnetizing the inductor after the DPT → no continuous current flow!

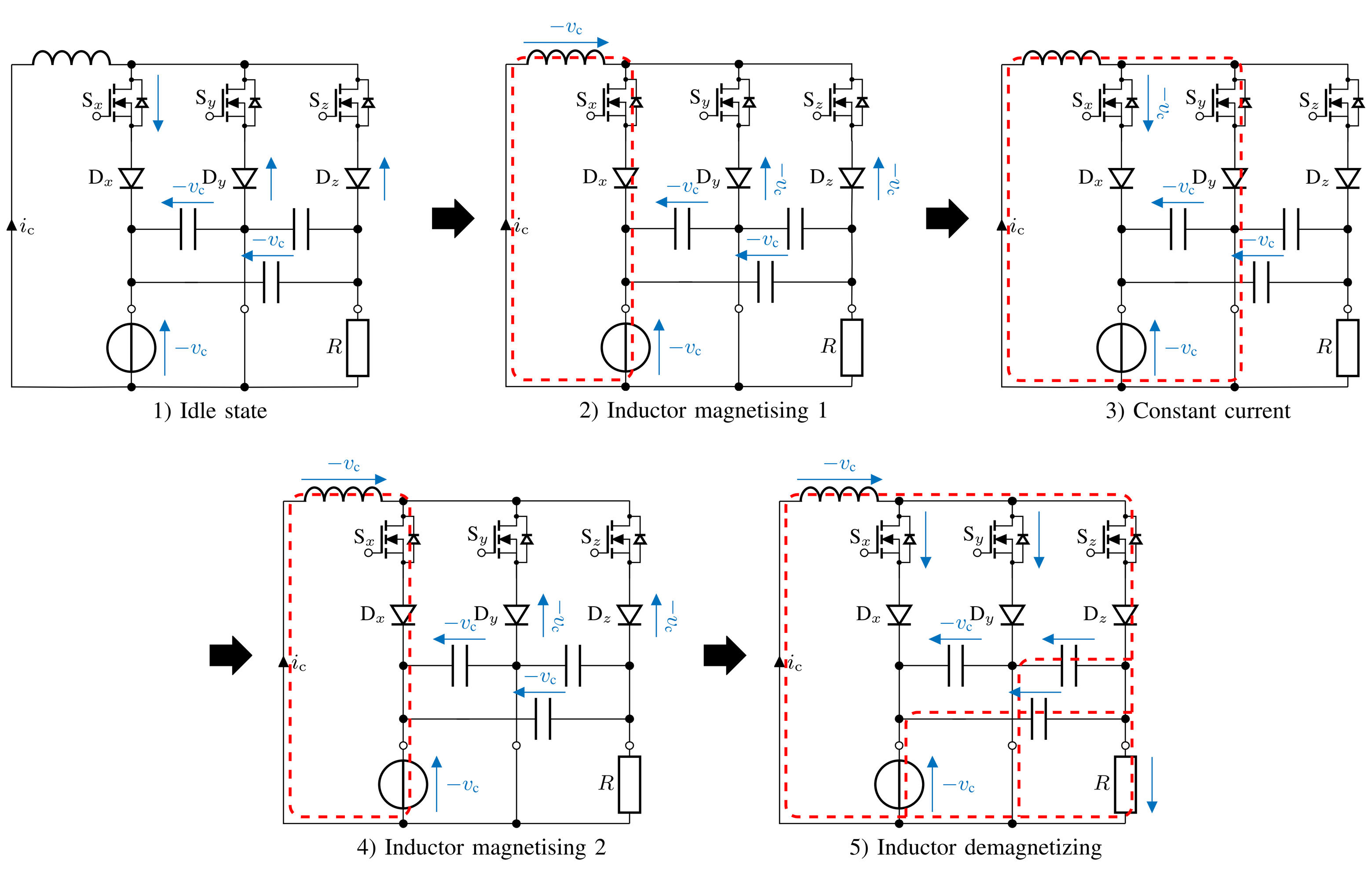

Fig. 2: Schematic representation of the basic circuit diagram of the commutation cell for the different switching states during a DPT to determine the switching behaviour and switching losses of S_x, D_x, S_y and D_y.

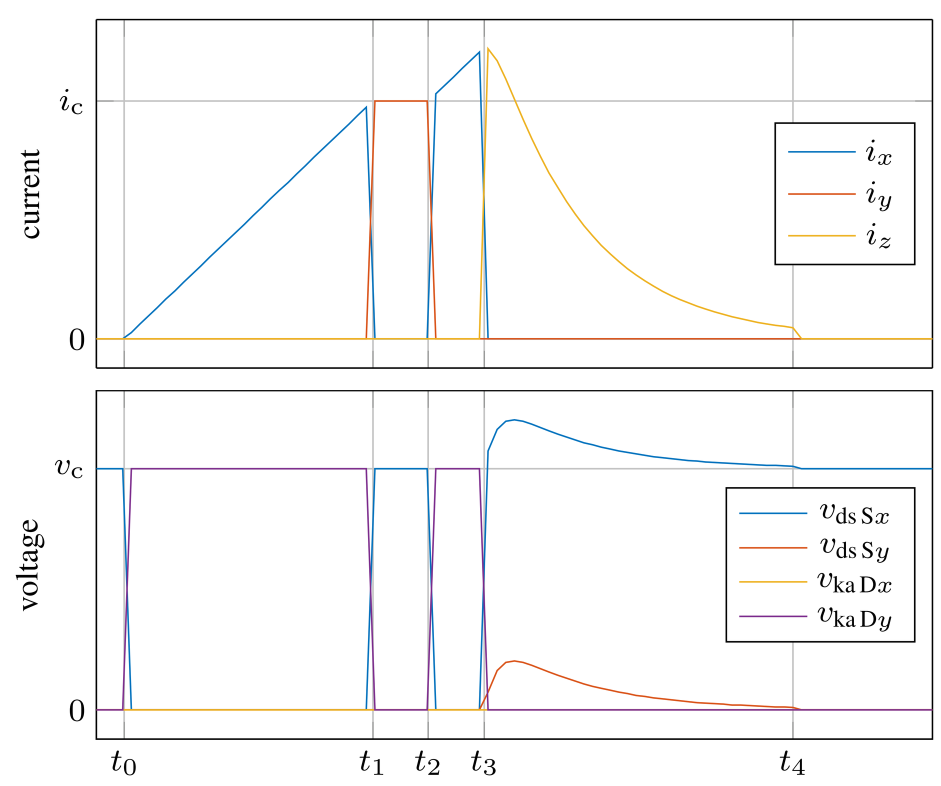

Fig. 3: Idealised voltage and current curves during the DPT. After the idle state ($t > t_0$), the current in the DC link inductor is first ramped up to it's desired value. Then the switching operations for the measurement take place at $t = t_1$ and $t = t2$. Once the current has commutated back to branch x after the test, L_{dc} can be demagnetised via R from $t > t_3$.

Developed Commutation Cell

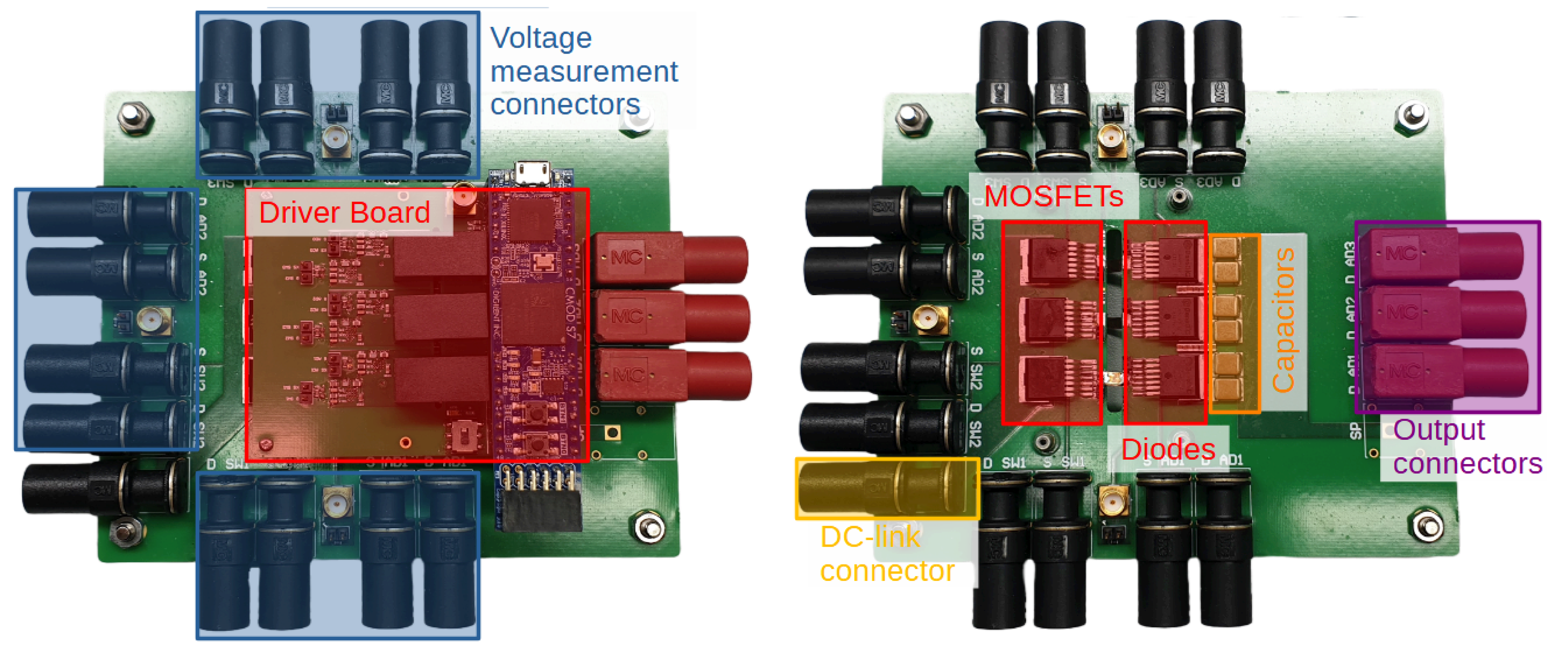

Fig. 4: Designed commutation cell with SiC MOSFETs and SiC SBDs without external components. The driver board for controlling the MOSFETs is stacked on top of the PCB with the power semiconductors and connectors.

- **SiC MOSFETs** ($v_{DS,max} = 900\,V$, $R_{ds(on)} = 65\,m\Omega$).
- **SiC Schottky diodes** ($v_{KA,max} = 1.2\,kV$).
- Ceramic capacitors in close proximity to the RVB switches, other passive components, measurement devices and voltage source connected externally.

Experimental Results

- The proposed test method was verified with the developed commutation cell.
- Expected and measured current- and voltage waveforms show good agreement.
- The test method is feasible for the characterisation of RVB switches in CSIs.

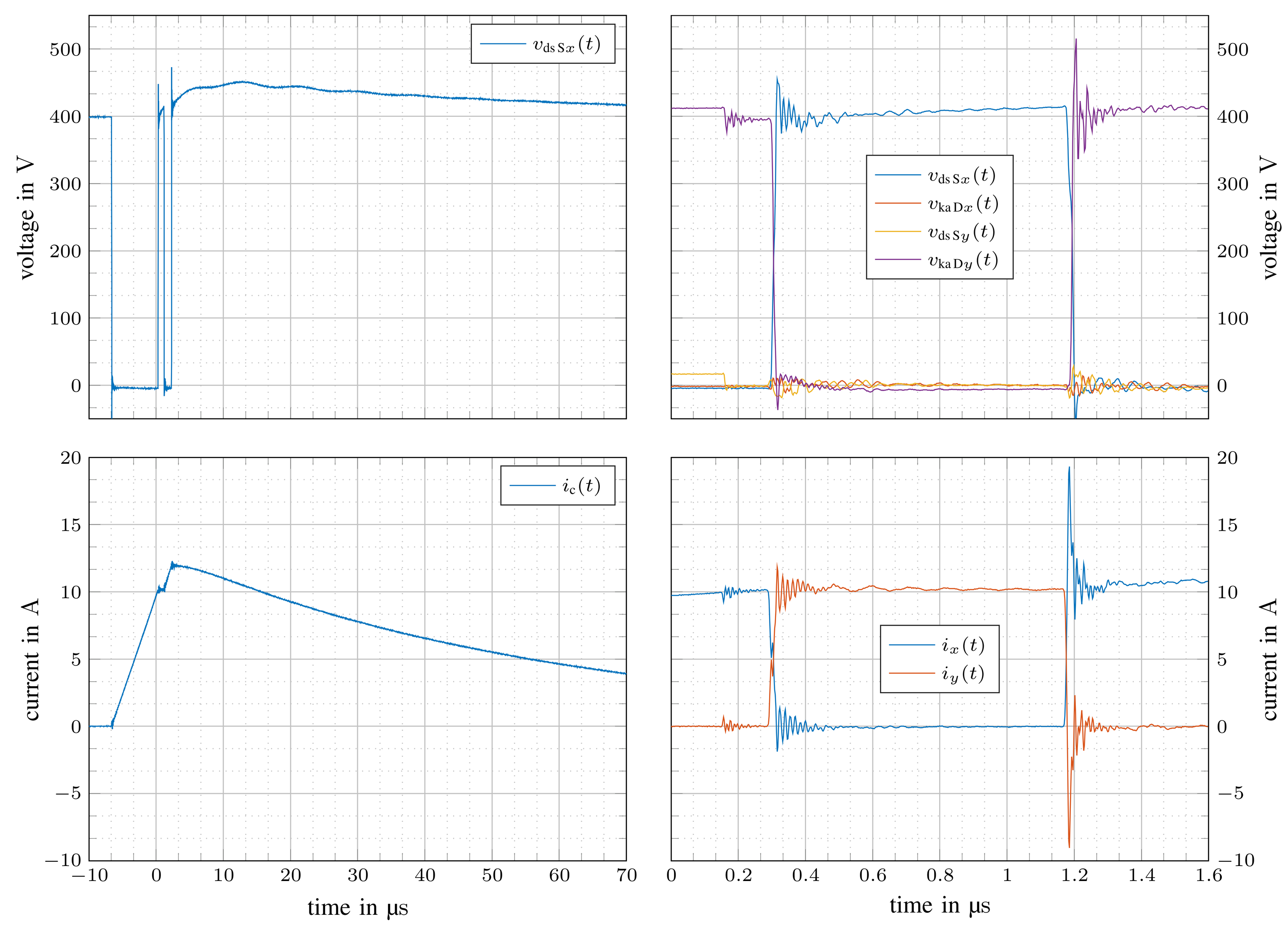

Fig. 5: Current and voltage waveforms of the semiconductor switches, measured during an exemplary switching process.

commutation voltage	passive components			timings			
v_c	R	L_c	C_f	$t_1 - t_0$	$t_2 - t_1$	$t_3 - t_2$	$t_4 - t_3$
V	Ω	µH	µF	µs	µs	µs	µs
400	4	272	1	6.8	1	1	900

TABLE I: Parameters of the supply voltage, passive components, and timings for the pulse test in Fig. 5.

Conclusion

- Novel test method for determining switching losses of CSIs presented.
- Extends classic commutation cell (with current source) by third switch branch, passive components and a voltage source.
- Advantage: no continuous current flow prior to and after the test.
- Hardware prototype built and tested → proposed method is suitable for characterising the switching behaviour of RVB switches.

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