Current Source Inverter – Switching Loss Measurement

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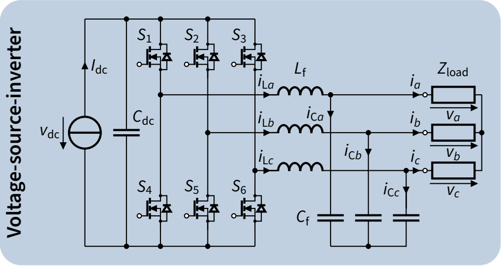
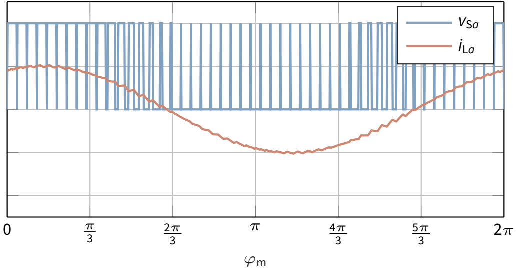
Motivation (I)

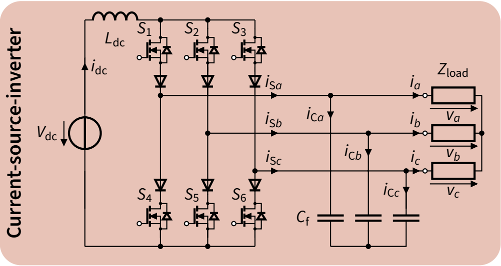
- Most used topology for 3-Φ drives: 2-lvl PWM voltage source inverter (VSI).
- Newly available WBG-switches offer operation at high switching frequencies.
- Problem: high $\frac{dv}{dt}$ causes isolation stress, losses due to stray capacitances, EMI, bearing currents, overvoltages with long cable runs, ...
- Filter for VSI almost always necessary (complicated design, bulky, lossy, expensive).

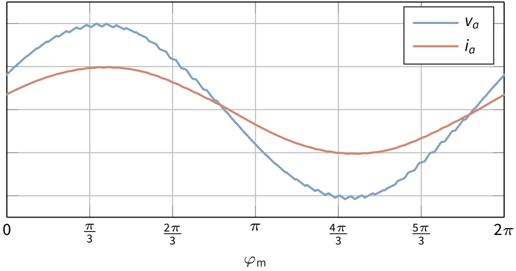




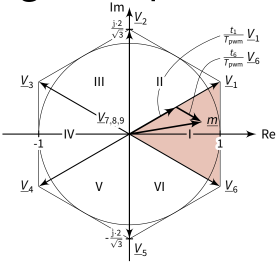
Motivation (II)

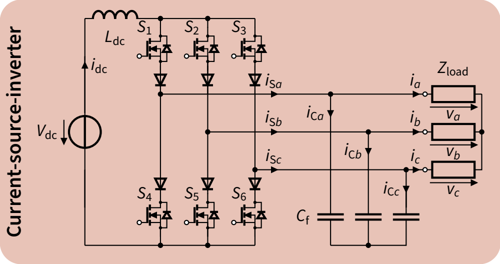
- Possible solution: current source inverter (CSI).
- Similar to thyristor based "B6C" inverter (but with PWM).
- DC-link inductor imprints a constant current (instead of voltage) at the DC-link.
- For inductive loads (like electric machines): "small" filter capacitors at the output are needed.
- Smooth output voltage and current waveforms due to inherent second order filtering (L_{dc} + C_f).
- Big drawback: reverse voltage blocking switches are necessary! This can be possibly addressed by bidirectional GaN Switches.





Operating Principle of the CSI





- 6 active switching states (considering interlock times) and 3 zero states.
- The node current pattern of each state is transformed to complex vector representation ($\underline{V}_1 \ldots \underline{V}_9$). With $\underline{I}_{S1} = \underline{V}_1 \cdot i_{dc}$
- Arbitrary output current vector $i_S = \underline{m} \cdot \bar{i}_{dc}$ and $\underline{m} = M\, e^{j\,\varphi_m}$ can be synthesized by linear combination of two adjacent vectors and one zero vector in a switching interval T_{pwm}.

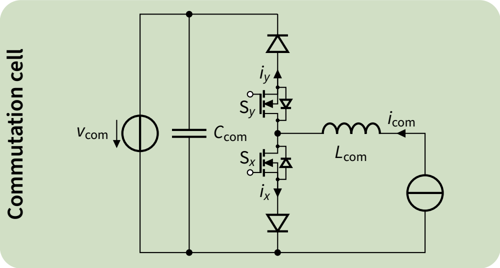
$$\begin{bmatrix} t_x \\ t_y \end{bmatrix} = \frac{1}{f_{pwm}} \cdot \begin{bmatrix} \Re(\underline{V}_x) & \Im(\underline{V}_x) \\ \Re(\underline{V}_y) & \Im(\underline{V}_y) \end{bmatrix}^{-1} \cdot \begin{bmatrix} \Re(\underline{m}) \\ \Im(\underline{m}) \end{bmatrix}$$

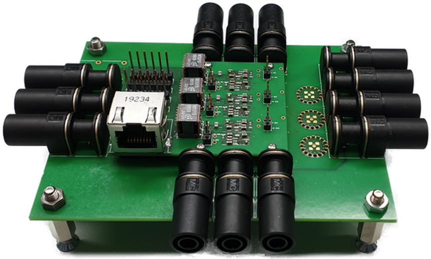
$$\frac{1}{f_{pwm}} = T_{pwm} = t_x + t_y + t_0$$

$$\underline{i}_S = \frac{\bar{i}_{dc}}{T_{pwm}} \cdot \left(\underline{V}_x \cdot t_x + \underline{V}_y \cdot t_y + \underline{V}_0 \cdot t_0 \right)$$

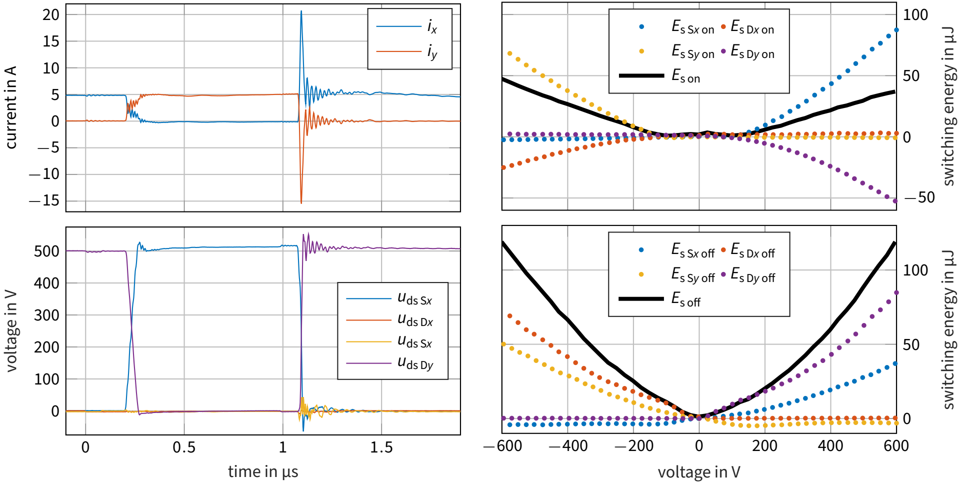
CSI Commutation Cell

- Switching loss measurement with commutation cell.
- Consists of two switching elements involved in the commutation process (e.g. S_1 and S_2).
- Variation of commutation Voltage v_{com} and commutation current i_{com} possible.
- Commutation cell developed and built:
  - For SiC-based devices in TO-263-7 package (Dual MOSFET or MODFET+Diode)
  - Includes fixtures for current and voltage measurement.
  - Planned structure of the full inverter is maintained (similar commutation loop inductance).
  - First measurements carried out.





Measurement Results



Conclusion and Outlook

Conclusion

- Motivation for investigation of the current source inverter presented.
- Basic operating principle was described.
- Introduction to switching loss measurement with a commutation cell.
- First measurement results were presented.

Outlook

- Measurement of switching losses over a larger current range.
- Improvement of current measurement with in-house developed PCB Rogowski coils.
- Design of a full-scale inverter with the help of the obtained measurement data.

Thank you for your attention!

Questions?