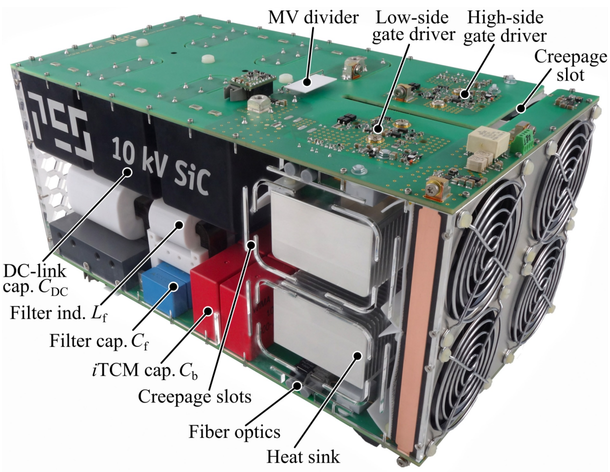
Highly Efficient 10kV SiC-Based Solid-State Transformers

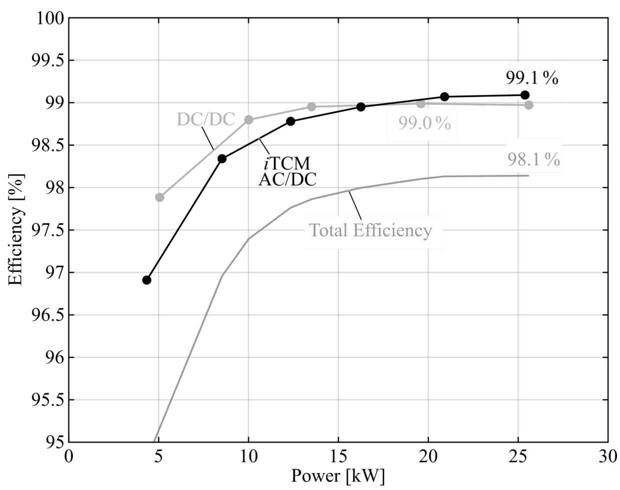
spotlight-esc.ethz.ch/2018/09/19/highly-efficient-10kv-sic-based-solid-state-transformers

The increasing number of high-power DC applications such as data centers or electric vehicle charging facilities demand for highly efficient and highly compact Medium-Voltage (MV) connected DC power supplies. Novel 10kV SiC power semiconductors enable the realization of Solid-State Transformers (SSTs) featuring a supreme efficiency and power density compared to conventional MV-AC-to-400V-DC solutions.

Solid-State Transformers (SSTs) are power electronic interfaces between a MV grid and a low-voltage grid. Similar to conventional transformers, they provide galvanic isolation but additionally offer control and protection features as well as the capability to operate in DC grids. Due to the outstanding performance of the latest generation 10kV SiC power switches, exceptionally high efficiencies are achieved, while at the same time extremely high switching frequencies in the range of 75kHz are employed, enabling a significant downsizing of the magnetic components such as inductors and the MV transformer which provides the galvanic isolation. Due to the high performance in terms of efficiency and power density, these SSTs can e.g. be used as MV-connected DC power supplies for data centers, battery charging facilities for electric vehicles, or in future deep sea factories, which have to be supplied with electric energy via long MV cables from the shore.

Embedded in the National Research Program 70 of the Swiss National Science Foundation, a 25kW, 3.8kV-AC-to 400V-DC SST was realized at the Power Electronic Systems Laboratory, whereby multi-objective optimization methods have been employed to achieve the highest possible performance of the system. In the course of the project, e.g. an innovative converter topology with superior performance and ultra-fast protection circuits for the 10kV SiC devices have been developed. Furthermore, special insulation materials have been characterized and utilized for the insulation of the magnetic components in order to guarantee a reliable operation over a long lifetime.





The left part of the figure shows the realized 25kW bidirectional 3.8kV single-phase AC-to-7kV-DC power factor correction (PFC) stage achieving a power density of 3.3kW/L and a full-load efficiency of 99.1%. On the right hand side, the measured efficiencies of the AC/DC converter and of a DC/DC converter output stage (7kV-DC-to-400V-DC) and of the total SST are shown. While similar SSTs up to now reach an efficiency of 96%, the SST at hand reaches 98.1%, i.e. the losses are cut in half.

More information about the project can be found on the project website.

The people involved in this project are Daniel Rothmund, and ESC member, Professor Johan W. Kolar.

Prof. Kolar is head of the Power Electronic Systems Laboratory (PES). The research at PES opens up new fields of applications and drives the innovation of power electronics systems in close partnership with both Swiss and international industry. In line with the focus areas of ETH Zurich, fundamentally new concepts, e.g., for sustainable energy systems, sustainable mobility, future datacenters, and medical applications, are of primary interest, along with general scientific challenges and the pursuit of excellence and an internationally leading reputation.

Tweet: Highly Efficient 10kV SiC-Based Solid-State Transformers