Solid-State Transformers – Key Design Challenges, Applicability, and Future Concepts

Abstract

This tutorial introduces participants to the Solid-State Transformer (SST) concept in a comprehensive and easy-to-follow fashion. After a brief review of transformer basics and of the SST concept history, the motivation, requirements, and challenges associated with SST applications in future locomotives, smart distribution systems, and source-side (e.g., connection of wind power generators to a DC collecting grid, or of photovoltaic power plants to the MV AC gird) as well as load-side applications (e.g., medium voltage interface of high-power EV battery chargers or general MV-connected power supplies) are identified.

Conceptual aspects like, e.g., single-cell vs. multi-cell converter approaches, isolated front-end vs. isolated back-end converter architectures, reliability of multi-cell converters, protection, etc. are discussed. Furthermore, the operation of high-power isolated DC/DC converters is detailed, and modern SiC power semiconductors, medium-frequency transformer design, multi-cell converter control system partitioning, etc. are discussed. Finally, aspects of testing high-power medium-voltage systems and construction issues of modular medium-voltage converters are summarized. In order to render the discussions more tangible, the challenges and potential solutions are illustrated using an exemplary 1MVA multi-cell distribution level SST system.

Finally, future concepts such as unidirectional SSTs are addressed, and the most promising application scenarios for SSTs as well as future research areas are identified, before the tutorial concludes with a critical evaluation of the SST concept. The tutorial is tailored to serve the interests of a broad audience with academic or industrial backgrounds.

Contact Information

Prof. Dr. Johann W. Kolar
Jonas E. Huber

ETH Zurich
Power Electronic Systems Lab.
Physikstrasse 3
8092 Zürich
Switzerland

Phone: +41 44 632 9764
Fax: +41 44 632 1212

E-mail: kolar@lem.ee.ethz.ch
huber@lem.ee.ethz.ch

Presenter Biographies

Johann W. Kolar is a Fellow of the IEEE and received his M.Sc. and Ph.D. degree (summa cum laude) from the University of Technology Vienna, Austria. He is currently a Full Professor and the Head of the Power Electronic Systems Laboratory at the Swiss Federal Institute of Technology (ETH) Zurich. Dr. Kolar has proposed numerous novel PWM converter topologies, and modulation and control concepts, e.g., the Vienna Rectifier, the Swiss Rectifier, and the Three-Phase AC-AC Sparse Matrix Converter and has published over 600 scientific papers in international journals and conference proceedings and has filed more than 100 patents. He received 10 IEEE Transactions Prize Paper Awards, 10 IEEE Conference Prize Paper Awards, the SEMIKRON Innovation Award 2014, the Middlebrook Achievement Award of the IEEE Power Electronics Society, and the ETH Zurich Golden Owl Award 2011 for Excellence in Teaching. The focus of his current research is on ultra-compact and ultraefficient converter topologies employing latest power semiconductor technology (SiC and GaN), Solid-State Transformers, Power Supplies on Chip, and ultra-high speed and bearingless motors.

Jonas E. Huber received his MSc degree (with distinction) from the Swiss Federal Institute of Technology (ETH) Zurich, Switzerland, in 2012. He then joined the Power Electronic Systems Laboratory, ETH Zurich, as a PhD student, where his main research interests are in the area of solid-state transformers for smart grid applications, focusing on the analysis, optimization, and design of high-power multi-cell converter systems, reliability considerations, control strategies, and grid integration aspects, among others.