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Power Converters for Energy Storage Applications

-Analysis and Design From Theory to Practice-

***Abstract*—** Power electronics and static power converters play significant role in industrial applications, power generation and transmission, home appliance, transportation and so on. In most of the power conversion applications, we are facing higher and higher demand for a device that is able to store and re-store certain amount of energy. In another words, an energy storage device is required. Currently, several different energy storage technologies are available: flywheel, electrochemical double layer capacitors (EDLC), fuel-cells (FC) and electrochemical batteries. An energy storage device cannot be directly connected to a power conversion system. An interface ac/dc or dc/dc power converter between the energy storage and the system is required.

In first part of the tutorial background and history of power conversion systems will be briefly presented. Needs for the use of energy storage in these applications will be identified and discussed.

Background theory of energy storage devises will be given in the second part of the tutorial. We will particularly discuss electrochemical batteries and ultra-capacitors.

In the third part of the tutorial, typical power conversion systems with energy storage such as VSD, renewables (wind & PV), micro-grid, autonomous diesel generators, STATCOMs, UPS and transportation will be discussed.

In the fourth part the tutorial, we will discuss sizing and selection of the energy storage module. We will see how rated voltage and capacity of the energy storage module has to be selected. Then, losses and efficiency of the module will be discussed. At the end, the module thermal design will be considered too.

Further, some details of interface dc-dc converters will be given in the fifth part of the tutorial. The converter specification and requirement will be discussed. State of the art topologies will be compared according to the applications requirement. Some new topologies will also be presented and discussed in details. Design guidelines will be given.

Interface ac-dc power converters for grid and micro-grid applications will be discussed in the sixth part of the tutorial. Single stage and double stage voltage-source and current-source topologies will be compared and analyzed. Some new topologies will be analyzed in details.

Modeling and control aspects of entire energy storage system will be discussed in the seventh part of the tutorial. Firstly we will discuss low-level control of the interface converter (control of the battery current and SoC.) Then, control of overall system, such as grid current control, power flow control, etc..etc. will be discussed. Different control strategies and architectures will be discussed and analyzed.

Several case studies and design examples will be given in concluding part of the tutorial. Firstly, overall energy storage system will be designed. Then, the interface power converter will be analyzed and designed. At the end, overall system control and control of power converter will be designed.

This tutorial is aimed at power electronics engineers, professionals and graduate students who want to improve their knowledge and understanding of advanced energy storage devices, interface converters and their application in power conversion, nowadays as well as in the near future.

Tutorial Content:

Instructor:

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Dr. Petar J. Grbović received the Dipl. Eng. (B. Sc) and M.Sc. degrees from the School of Electrical Engineering, University of Belgrade, Serbia, in 1999 and 2005, and the Doctor (Ph.D) degree from the Laboratoire 'Électrotechnique et d'Électronique de Puissance de Lille, l'Ecole Centrale de Lille, France in 2010.

From March 1999 to February 2003, he was an R/D Engineer with RDA Co, Belgrade. From November 2000 to June 2001, he was a Consulting Engineer with CESET Italy (a division of Emerson Appliance Motors Europe). From March 2003 to April 2005, he was with the R&D Department, PDL Electronics, Ltd., Napier, New Zealand. Since April 2005 until July 2010 he was working with Schneider Toshiba Inverter Europe, Pacy-Sur-Eure, France, as Power Electronics Group Expert. Since September 2010 until August 2011 he was with General Electric Global Research, Munich, Germany. Since September 2011 he is with HUAWEI Technologies, Europe Energy Competence Center in Munich/Nuremberg, Germany, where he works as a Senior Expert in the area of power electronics and power conversion. Since 2016 he is a scientific member of Center of Power Electronics and Drives, Roma TRE University, Rome, Italy.

Dr. Grbović published over 50 IEEE conference/journal papers, 10 IEEE tutorials and a book "Ultra-capacitors in power Conversion Systems: Analysis, Modeling and Design in Theory and Practice". He has 14 patents granted and six patent application pending. The focus of his research is on application of advanced energy storage devices, power converter topologies, advanced power semiconductor devices, control of power converters and semiconductor devices.