Ultra-Capacitors In Power Conversion: Analysis, Modeling And Design In Theory And 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 some of these applications, the energy storing time is quiet short, couple of seconds up to several tens of seconds. Currently, the two technologies well fit in these applications: flywheel energy storage and electrochemical double layer capacitors (EDLC), well known as ultra-capacitors. In this tutorial, we will discuses application of ultra-capacitors in power conversion, with particular attention on analysis, modeling and design.

- In first part of the tutorial background and history of power conversion systems will be presented. Needs for the use of energy storage in these applications will be identified and discussed.
- Background theory of ultra-capacitors will be given in the second part of the tutorial. The ultra-capacitor modeling with attention to the application oriented model will be given. Method to compute the ultra-capacitor current stress and power losses for different conditions will be discussed. We will see how the ultra-capacitor losses depend on the charge/discharge frequency and how the losses can be computed when the charge/discharge current frequency is in range of mHz (very low frequency) and in range of couple of Hz (low frequency). Some application examples, such as variable speed drives with braking and ride through capability will be given.
- In the third part of the tutorial, structure of a typical power conversion system with ultra-capacitor energy storage will be presented. Different power conversion systems such as variable speed drives, renewable applications (wind for example), autonomous diesel generators, STATCOM devices with short term active power capability and short term UPS will be discussed. The main functional blocks of such systems will be identified.
- In the fourth part the tutorial, we will discuss selection and design of the ultra-capacitor module. We will see how the ultra-capacitor rated voltage and capacitance should be selected according to the application requirement. Then, losses and efficiency of the ultra-capacitor module versus size and cost will be discussed. Couple of application examples such as variable speed drives will be given. Finally, some aspects of the ultracapacitor module design will be presented. Series connection of elementary ultra-capacitor cells and voltage balancing issue will be discussed. The module thermal design will be considered too.
- Further, some details of the interface dc-dc converters will be given. Needs for the dc-dc converter will be discussed. State of the art topologies will be compared according to the applications requirement and design guidelines will be given. Couple of design examples will be given.
- In concluding part of the tutorial, trends in development of the ultra-capacitors and applications will be discussed.

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

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Instructor Bio

Petar J. Grbović received the B.Sc. and M.Sc. degrees from the School of Electrical Engineering, University of Belgrade, Serbia, in 1999 and 2005, and the Ph.D. degree from the Laboratoire d'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, Munich, Germany, where he works as Senior Expert in the area of power electronics and power conversion.

Dr. Grbović holds four US patents and nine US and European patents pending. He is IEEE senior member of Power Electronics and Industrial Electronics society. The focus of his research is on application of advanced energy storage devices, active gate driving for high power IGBTs and JFET SiC, power converter topologies, advanced power semiconductor devices and control of power converters and semiconductor switches.