

Design Considerations for Energy Storage Systems based on Supercapacitors and Batteries

Presenter(s):

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Brief description:

There is a huge expectation form Energy Storage technology to solve a wide range of problems that our society faces today, from addressing the unpredictability of renewable energy in stationary applications, to matching the travel range of gasoline powered cars. In most of these energy storage applications, electrochemical energy storage that can store directly electrical power/energy by means of rechargeable batteries and supercapacitors, is seen as the most convenient alternative.

This tutorial aims at analysing the main aspects needed in the design of an electrochemical energy storage system. First, the basic energy storage device behaviour will be discussed including several supercap and battery technologies that will be compared. Then the equivalent modelling, extraction of the equivalent parameters that can be used in the power loss modelling will be presented. Implementation aspects related to the assembly of devices in stacks, the need to implement cell voltage equalisation/balancing and the design aspects when hybrid battery/supercapacitor systems are developed will be analysed. The tutorial will conclude with very specific aspects related also to the design of the power converters for interfacing the energy storage stack (including the choice of cell size) to a particular application will be also discussed by presenting two design case studies.

Outline:

- *Behaviour of Electrochemical Energy storage devices*
- *Extracting the parameters for the Equivalent Models*
- *Techniques for accurate power loss estimation in energy storage devices*
- *Cell voltage balancing circuits*
- *Choosing the Supercap/Battery ratio in a Hybrid Energy Storage System*
- *Design Considerations of a Power Converter for Energy Storage Systems*

Relevant publications:

- [1] C. Klumpner, G. Asher, GZ Chen, "Choosing the Power Electronic Interface for a Supercapattery Based Energy Storage System", Proc.of IEEE PowerTech (PES), paper #799, June 2009.
- [2] P. Kulsangcharoen, C. Klumpner, M. Rashed, G. Asher, "A New Duty Cycle Based Efficiency Estimation Method for a Supercapacitor Stack Under Constant Power Operation", IET Proc. of Power Electronics Machines and Drives Conference PEMD'10, paper Tu2.4.3, April 2010.
- [3] P. Kulsangcharoen, C. Klumpner, X.H. Zhou, C. Peng, G.Z. Chen, M. Rashed, G. Asher, "Efficiency Evaluation of a Novel Supercapattery Stack with a Power Electronic Interface for Energy Storage Systems", Proc. of PCIM'10, pp. 398-403, paper #066 on conf. CD-ROM, May 2010.
- [4] M. Rashed, C. Klumpner, G. Asher, "Hybrid Cascaded Multilevel Converter with Integrated Series Active Power Filter for Interfacing Energy Storage System to Medium Voltage Grid", Proc. of IEEE International Power Electronics Conference IPEC'10, pp. 1236-1243/(23P1-5), June 2010.

- [5] P. Kulsangcharoen, **C. Klumpner**, M. Rashed, G. Asher, "Characterization of Energy Storage Devices for Constant Power Applications", Proc of IECON'10, paper #10707, pp. 1799-1804, 2010.
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- [7] P. Kulsangcharoen, **C. Klumpner**, M. Rashed, G. Asher, "Evaluation of a Flyback Regenerative Voltage Equalisation Circuit for Series-Connected Supercapacitor Stacks", Proc. of European Power Electr.&Apps Conf EPE'11, paper#0803, ISBN: 9789075815153, Sept 2011.
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- [9] D. De, **C. Klumpner**, M. Rashed, C.Patel, P. Kulsangcharoen, G.Asher, "Achieving the Desired Transformer Leakage Inductance Necessary in DC-DC Converters for Energy Storage Applications", IET Proc. of Power Electr.Machines&Drives Conf. PEMD'12, paper #213, Mar 2012.
- [10] D. De, **C. Klumpner**, C. Patel, P. Kulsangcharoen, M. Rashed, G. Asher, "Modelling and control of a multi-stage interleaved DC-DC converter with coupled inductors for super-capacitor energy storage system", IET Power Electronics Journal, Vol. 6, No. 7, pp. 1360-1375, 2013.
- [11] M.F. Romlie, M. Rashed, **C. Klumpner**, G. Asher, "An analysis of efficiency improvement with the installation of energy storage in power systems", IET Proc. of PEMD'14, paper #521, 2014.
- [12] P. Kulsangcharoen, M. Rashed, **C. Klumpner**, D.De, C.Patel, G.Asher, "Experimental evaluation and efficiency optimisation of a grid-connected converter for household energy storage applications", IET Proc. of Power Electr. Machines&Drives Conf PEMD'14, paper #402, Apr 2014.
- [13] P.Kulsangcharoen, **C.Klumpner**, M.Rashed, G.Asher, G.Z.Chen, S.Norman, "Assessing the Accuracy of Loss Estimation Methods for Supercapacitor Energy Storage Devices Operating under Constant Power Cycling", Proc.of European Power Electr&Apps Conf EPE'14, paper#546, Aug 2014
- [14] **C. Klumpner**, A. El Boudali, "Assessing the benefits of installing energy storage in a household equipped with photovoltaic panels", Proc. of 14th Int Conf on Sustainable Energy Tech.
- [15] A. Fares, **C. Klumpner**, M. Sumner, "Development of a battery energy loss observer based on improved equivalent circuit modelling", Prof of EPE'16, paper #0515, 2016.
- [16] **C. Klumpner**, M. Rashed, D. De, P. Kulsangcharoen, C. Patel, G. Asher, "Experimental validation of the solid state substation with embedded energy storage concept", Proc of 8th Annual IEEE Energy Conversion Congress & Exposition (ECCE 2016), 18-22 September 2016.

Presenter's biography:

Dr. Christian Klumpner (S'00, M'02, SM'08) received the Ph.D. degree in electrical engineering in 2001 from the "Politehnica" University of Timisoara, Romania. From 2001 to 2003, he was a Research Assistant Professor in the Institute of Energy Technology, Aalborg University, Denmark. Since October 2003, he has been a Lecturer (Associate Professor from 2011) with the Department of Electrical Engineering, University of Nottingham, UK. His current research interests include power electronics for various applications such as AC drives, connecting renewable energy sources and energy storage devices to the AC power grid. Dr. Klumpner received the Isao Takahashi Power Electronics Award in 2005 at the International Power Electronics Conference organized by the Institute of Electrical Engineers of Japan (IEEJ) in Niigata. He is also a recipient of the 2007 IEEE Richard M. Bass Outstanding Young Power Electronics Engineer Award.