Modeling and Simulation of Hybrid Energy Storage Systems

Biswajit Ray
Bloomsburg University of Pennsylvania
bray@bloomu.edu

Abstract

The hybrid energy storage system (HESS) concept is gaining importance in applications requiring load leveling, high-density energy storage, and emergency power. Energy sources used in modern HESS include high performance batteries such as Li-Ion, ultracapacitors, and flywheels. HESS provides an excellent platform to teach system-level modeling and simulation while integrating aspects of electrical, mechanical, and thermal systems. Circuit-level models of energy storage devices such as batteries and ultracapacitors can be developed from manufacturer provided performance characteristics. Similarly, a circuit-level model of a generator can be developed from its terminal characteristics and electromagnetic parameters. An example HESS for avionics applications, shown in Figure 1, connects various energy sources to the dc power bus via dc-dc power converters. These bidirectional power converters play a key role in designing HESSs since they let energy sources of various voltage and power levels support the system load in a controlled and predictable manner. Additionally, energy-dense and power-dense storage devices can be integrated to optimize the weight and performance of HESSs by effective use of dc-dc power converters. Accordingly, modeling of a switching power converter of the type shown in Figure 2 is an integral part of the HESS design and implementation process.

Exploration of modeling and simulation of HESSs is possible using the Matlab/Simulink software. Various subsystems can be developed to model the energy sources, dc-dc converters, and loads. The dc-dc power converters can be analyzed by developing switching as well as average models. Various subsystems are connected to develop multiple HESS configurations. A supervisory control algorithm can be implemented to control the sharing of power and energy among various energy sources. One of the goals of this HESS modeling and simulation effort is to optimize the design in terms of electrical and thermal performance, power and energy efficiency, mass, and volume of the overall system. From a pedagogical point of view, modeling and simulation of HESSs presents an excellent platform to integrate various curricular content including modern energy storage devices, electrical and electronic circuits, electrical machines and power systems, control systems, and power electronics.

Proceedings of The 2014 IAJC-ISAM International Conference
ISBN 978-1-60643-379-9

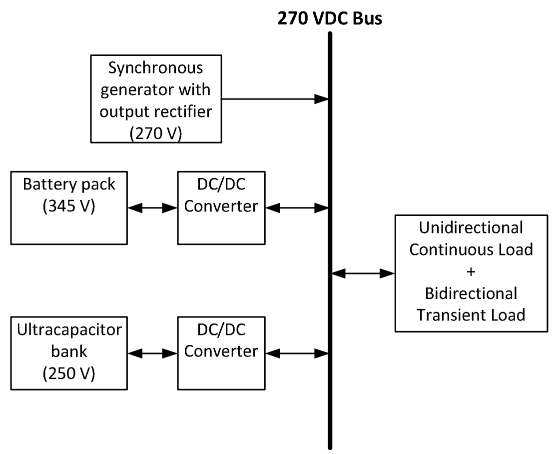

Figure 1: An example HESS system.

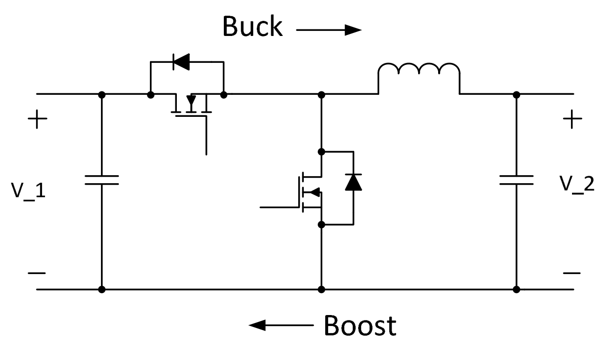

Figure 2: Bidirectional buck/boost converter.

Biography

BISWAJIT RAY received his B.E., M.Tech., and Ph.D. degrees in Electrical Engineering from University of Calcutta (India), Indian Institute of Technology-Kanpur (India), and University of Toledo (Ohio), respectively. He is currently the coordinator, and a professor, of the Electronics Engineering Technology program at Bloomsburg University of Pennsylvania. Previously, he taught at University of Puerto Rico-Mayaguez, and designed aerospace electronics at EMS Technologies in Norcross, GA. Dr. Ray is active in power electronics consulting work for various industrial and governmental agencies. He may be reached at bray@bloomu.edu.