Electrochemical Capacitor Characterization for Electric Utility Applications

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(**Please Note:** This is an abstract of Stan Atcitty's Doctoral Presentation. The complete dissertation is available at no cost from Virginia Polytechnic Institute. Go to: http://scholar.lib.vt.edu/theses/available/etd-11162006-151143).

Electrochemical capacitors (ECs) have received a significant level of interest for use in the electric utility industry for a variety of potential applications. For example, ECs integrated with a power conversion system can be used to assist the electric utility by providing voltage support, power factor correction, active filtering, and active/reactive power support. A number of electric utility applications have been proposed but, to date, ECs have not been very well characterized for use in these applications. Consequently, a need exists to gain a better understanding of ECs in association with electric utility applications.

ECs are attractive for utility applications because they have higher energy density than conventional capacitors and higher power density than batteries. ECs also have higher cycle life than batteries, which results in longer life spans. To better understand the system dynamics when ECs are used for utility applications requires suitable models that can be incorporated into the variety of software programs currently used to create dynamic simulations for the applications, programs such as PSPICE™, MATLAB Simulink™, and PSCAD™. To obtain a relevant simulation with predictive capability, the behavior of the EC on which the model is based must be well defined, which necessitates a thorough understanding of the electrical characteristics of these devices.

This paper and the associated research focus on the use of the electrochemical impedance spectroscopy (EIS) to develop nonlinear equivalent circuit models to better understand and characterize symmetric ECs (SECs) for electric utility applications. It also focuses on the development of analytical solutions to better understand SEC efficiency and energy utilization.

Representative static synchronous compensator (StatCom) systems, with and without SECs, were simulated and are discussed in the paper. The temperature effects on device ionic resistance and capacitance are also covered, as were the effect of temperature on maximum power transfer to a resistive load. Experimental data showed that the SEC's double-layer capacitance and ionic resistance are voltage dependent; therefore, a voltage-dependent RC network model was developed and validated. The results illustrate that this type of model mimicked the experimental SEC better than traditional electrical models.

Analytical solutions, which are a function of operating voltages, constant current, and ionic resistance, were developed for the efficiency and energy utilization of an SEC. The operating voltage method is an important factor in system design, because the power conversion interface is typically limited by a voltage window and, thus, can determine the performance of SECs during charge and discharge. If the operating voltage window is not properly selected, the current rating of the system can be reduced, which limits the SECs performance.

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