Modeling of Supercapacitor

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Abstract

Low cost high energy density batteries that can be charged and discharged rapidly are required in a number of applications. Tapping energy from renewal resources such as solar, wind and tide requires rapidly generated energy to be first stored and then used round the clock. Storing energy of a moving vehicle as it slows down and recovering it to accelerate the vehicle later can significantly increase fuel efficiencies of automobiles. Low cost batteries available today perform quite poorly in applications that require high (dis)charge currents. Adequately designed supercapacitors (SC) in principle allow present day high energy density batteries to be used effectively, as the momentary burden of high (dis)charge currents is taken up by the supercapacitors. The high capacitance of supercapacitors is achieved by increasing the surface area offered by the electrodes by choosing appropriate porous material such as activated carbon and by reducing the distance over which electric field is experienced to Debye length by using mobile ions in an electrolyte. Supercapacitors are typically modelled as a complex RC circuit. The parameters of such a model do not easily relate to the physical processes such as movement of ions in micro and meso voids in response to applied electric field and building up of charge in double layer. The present work uses a more fundamental transport process based approach, already available in the literature, to model a SC. In this work, a 1D transport model is developed for a SC with porous activated carbon coated electrodes inserted in an aqueous electrolyte solution. The model considers diffusive and convective movement of ions in a straight narrow channel in response to concentration gradient and local electric field. The governing equations are solved using COMSOL Multiphysics. The model explains variation of anodic and cathodic potentials during (dis)charging, recovery of potential drop during relaxation phase after high rate of discharge, limiting current densities, and effect of electrolyte concentration and diffusivities of ions on dynamics of (dis)charging process. The approximations used to obtain 1D model were dropped and simulations were carried with full 2D domain in COMSOL Multiphysics. The simulation results show that 1D model for a SC is quite adequate.
Key words: Supercapacitor, high capacitance, 1D transport model, energy storage, relaxation.