Developing Mathematical Models of Batteries in Modelica for Energy Storage Applications

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Battery modeling is a challenging field that has been receiving a great amount of interest recently due to the great push from the portable electronic devices and the electric and hybrid electric vehicles (EV/HEV) industries. Despite of the differences in the power ranges and battery sizes in these applications, the two industries share a common goal: developing a new generation of batteries that allow devices to run for a longer period of time, while operating within a range that maximizes the battery's service life. In both of these areas, accurate and efficient battery modeling is vital to help maximize the performance of a device and its battery.

In this paper, effective and systematic steps in the mathematical modeling of high-fidelity battery models for simulating energy storage systems (ESS) will be presented. Two approaches to battery modeling will be discussed in this paper: (1) equivalent electrical circuit approach, and (2) electrochemical approach.

While equivalent electrical models attempt to model the electrochemical physics of a battery using only electrical components, the resulting battery component, which is computationally inexpensive to incorporate into system models, has many limitations.
Electrochemical models on the other hand, are the most accurate because they describe the physics of a battery by explicitly representing the chemical processes that take place within it.

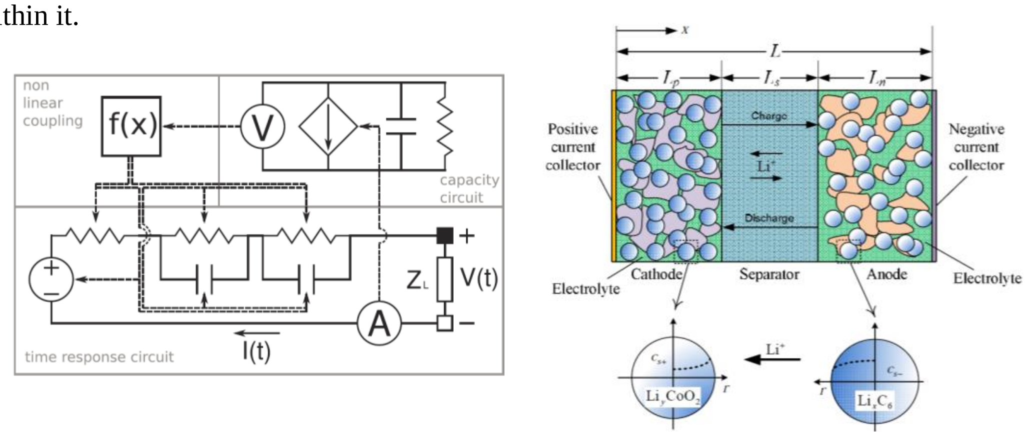

Figure 1. Schematic of an equivalent circuit model, and anatomy of a Lithium-ion cell

Capacity fade and thermal effects are incorporated into both the equivalent circuit and electrochemical battery components. The battery library also comes with a parameters identification worksheet which ensures a high level of fidelity in the battery components, making them suitable for a wide range of applications.

The battery models discussed in this article are developed based on the Modelica Standard Library specification 3.2.1 and commercialized as part of the Battery Component Library in MapleSim® 2015.