A Modelica Based Lithium Ion Battery Model

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In Battery Electric Vehicles (BEV) and Hybrid Electric Vehicles (HEV) the majority of car producers focus in lithium ion based battery concepts due to their high performance density in connection with reasonably high lifetime and acceptable thermal behavior. As these vehicles become more accepted on the market, the production numbers are supposed to increase with some positive pricing effect. It is likely that this will also make lithium ion batteries attractive for use in homes and other decentralized energy systems – especially in connection with renewable energy.

Practically all lithium ion based batteries show more or less troublesome aging behavior which reduces the lifetime to inacceptable levels, if no particular provisions are taken to avoid or reduce it. Aging appears as calendric and as cyclic effect according to the number of charging and re-charging events.

Aging effects are severely influenced by the thermal load on the battery. Therefore high performance battery systems need to be kept within a certain temperature range by cooling and sometimes heating.

For whatever application, in current battery systems single cells of a certain type are arranged in stacks, modules or packages through serial and parallel alignment of the cell. Cells can have cylindrical, prismatic or so-called coffee bag shape. Apart from the electrical interconnection, the cells are integrated in some thermal design concept to cool them and reduce aging. It should be noticed that car as well as energy system manufacturers design battery systems according to the needs of the general concept of their product. I.e. the design of the battery is not based on a unified single-type approach, but many different concepts are required to cover the large range of system requirements.

Therefore, the battery model presented in this paper uses the cell as a base unit to be parameterized with fairly simple data sheet and empiric input. With the help of pre-defined templates the user can easily set-up a battery model as an electrical and thermal system consisting of a single cell. Aging information is provided by an integrated aging system or user-defined approach.

While lithium ion battery cells are usually described by RC circuit elements, the electrochemical effects in lead-acid batteries are approximated in a separate model to take account of the specialties of this battery type.

In the following, a comprehensive Modelica model is introduced for the simulative description of the physical behavior of lithium ion battery cells packs for relevant aspects and use cases. It is part of the Modelon Battery Library, a commercial Modelica library to model battery cells and packs of various types, shape and grouping.

Thermal behavior, electrical behavior and the impact of the degradation due to aging are considered as they influence each other.

The model parameters to calculate the electrical behavior are to be derived from measurements; an optimization algorithm to obtain them is integrated in the package using the Optimization Library. Functions to validate the model against these measurements are included as well.

As an application example the simulation of an energetic energy storage system in the model of a battery electrical vehicle is shown.