Contribution ID: **552**

Type: **Oral Presentation**

Model Development for Thermal Management of Li-Ion Batteries from Cell Level to Total System Level

Monday, 22 May 2023 17:30 (15 minutes)

Li-Ion batteries are widely used for energy storage mediums because of their high volumetric and gravimetric energy capacities and proven mature technology level suitable for mass production. However, they have one key problem which is the heat generation during charging and discharging cycles. As the cells are getting too hot or too cold, battery life and performance decreases. If the heat generated from the batteries are not dissipated, there is even risk of explosion. To model the thermal behavior of the battery package one first needs to figure out the heat dissipated from a single cell, which can be set as an heat source value for the thermal modeling for the battery package. This can also be achieved with electrode scale continuum scale models, where Li transport in electrolyte and charge balance and Li diffusion in porous electrodes are modeled. However, electrode scale model would be over detailed to combine with a system level model.
First, cell level 2nd degree Thevenin's equivalent circuit model [1] was developed under Matlab (fig. 1 and fig.2).

Figure1. Thevenin's equivalent circuit model concept

Figure2. Thevenin's equivalent circuit model developed under Matlab

The model requires Open Circuit Voltage (Uoc) vs State of Charge (SOC) relationship as an input. The parameters Ro represents contact/ohmic resistance of the cell, R1-C1 represents cell polarization, R2-C2 represents diffusion process [2], which are determined by fitting terminal voltage (Ut)-SOC measurement. Different from the lead acid batteries the Li-Ion cells have exponential decrease in the terminal voltage when the terminal voltage is approaching the cut-off voltage. To mimic this behavior, the equivalent circuit components (R,C values) are not set to constant values, they are varying as a function of SOC.
The developed Thevenin Model is able to calculate SOC, Uoc, Ut, state of health (SOH), remaining capacity, useful capacity [3], thermal power and generated heat. The main purpose of building an equivalent circuit model is to calculate thermal power generated by the cell (Thermal_Power=(Uoc-Ut)* I_current) [4,5].
Battery Package level simulation is carried out with setting thermal power of Thevenin model as a heat source to model temperature distribution. Thermal conductivity properties are taken from [6].
This is achieved with Comsol finite element simulation software (fig. 3).

Figure 3. Temperature distribution within the battery package with active air cooling

Total system model is created to model system dynamics with varying terminal current. Total system model is composed of Grid Connection, Auxiliary Load, Power Control System, Power Management System, Convertors, HVAC System, Battery Management System and Battery Package. The developed equivalent circuit cell module is set in the heart of the battery package module. During operation the main heat sources are battery packages. The temperature distribution of the total system is calculated with FEM simulator.

The advantage of this approach is that the experimental data can be perfectly fitted to the model data. The drawback of this approach is that the heat that is generated during charge/discharge process is assumed to be homogenously distributed at the outer surface of the cell.

Participation

In-Person

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Session Classification: MS17

Track Classification: (MS17) Thermal Processes, Thermal Coupling and Thermal Properties of Porous Media: modeling and experiments at different scales