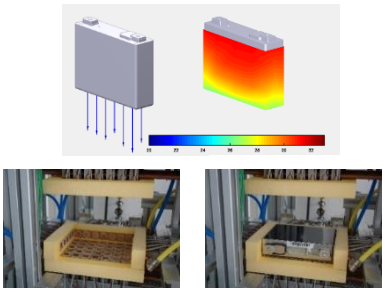
Capacity Area A1 Topic 1.3 Deliverable 1

An advanced model for thermal management of batteries

The goal is to increase lifetime, reliability and safety of Li-ion batteries, as well as to enable fast charging capabilities and operation without restrictions even under extreme temperature conditions. To design such a battery system and to forecast its behavior, more often the complete system, including electrical and thermal aspects, will be simulated in advance. A bottleneck doing this is the thermal characteristic of the battery cell and its corresponding model. To answer this question a unique test rig was developed at NTB, where the thermal behavior of lithium-ion cells can be characterized [1].

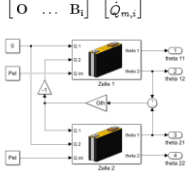
Experimental characterization of the cell thermal behavior



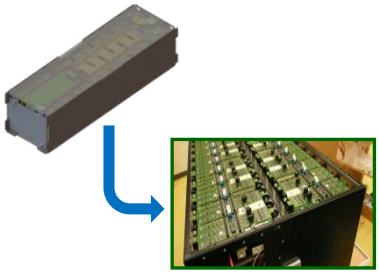
Reduced order model of thermal and electrical behavior

$$\begin{bmatrix}\dot{x}_1\\ \vdots\\ \dot{x}_i\end{bmatrix} = \begin{bmatrix}A_1 & \dots & O\\ \vdots & \ddots & \vdots\\ O & \dots & A_i\end{bmatrix}\cdot\begin{bmatrix}x_1\\ \vdots\\ x_i\end{bmatrix} + \begin{bmatrix}B_1 & \dots & O\\ \vdots & \ddots & \vdots\\ O & \dots & B_i\end{bmatrix}\cdot\begin{bmatrix}\dot{Q}_{m,1}\\ \vdots\\ \dot{Q}_{m,i}\end{bmatrix}$$

$$\begin{bmatrix}\vartheta_1\\ \vdots\\ \vartheta_o\end{bmatrix} = \begin{bmatrix}C_1 & \dots & C_i\end{bmatrix}\cdot\begin{bmatrix}x_1\\ \vdots\\ x_i\end{bmatrix}$$



Coupling of several cells to simulate and optimize the system



Step 1: Experimental characterization

The CTR (Cell-Test-Rig) at NTB is a unique apparatus to characterize the thermal behavior of battery cells. As a result, the local temperature and heat flux distribution at the surface under realistic load conditions are measured. The example above shows the conditions with bottom side cooling. The bottom side of the cell is actively kept at a constant temperature. As a result, the temperature distribution at the cell surface can be determined.

Step 2: Deduction of a reduced order thermal model

From the experimental temperature responses a reduced order model (ROM) can be derived, which accurately predicts the thermal behavior of a single battery cell. Within such a model, the cell surface is discretized into a number of input/output areas, through which the cell can exchange heat with its surroundings. Therefore, several cells can be coupled in simulation to form a battery module or battery system. This new approach of single cell model generation from experimental temperature and heat flux data enhances the quality and flexibility of the modeling.

Step 3: Design and optimization of battery system (including thermal management) through simulation

Such a general model allows very detailed prognoses about the final behavior of the battery system and the supporting equipment. In addition, optimization and parameter variation studies are possible. To reach the goals declared above the final temperature distribution throughout the battery system should be as homogeneous as possible.

[1] Rouven Christen, Gerhard Rizzo, Alfred Gadola and Max Stöck. “Test Method for Thermal Characterization of Li-Ion Cells and Verification of Cooling Concepts”, Batteries, Vol. 3(1), Art. 3, 2017.