Battery Performance Evaluation and Modelling for Stationary Applications

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CSEM is developing battery models for stationary energy storage systems. These models are dynamic and aim at predicting battery performance based on operating conditions. They can be industrially implemented in energy management systems (EMS) or storage sizing tools for grid and off-grid applications.

Battery energy storage systems (BESS) are the ultimate flexibility resource in electricity networks. They are attractive both to grid operators – to reduce congestion and respond to imbalances between production and consumption — and to "prosumers" — to reduce their reliance on utilities. Despite a decrease in cell costs with a learning rate of 18% for lithium-ion batteries, BESS remain expensive. Optimizing the choice of technology and their size is therefore essential to financial viability. These design choices and the subsequent operation of the systems are difficult because the effective capacity, efficiency and lifetime of BESS strongly depend on operating conditions.

To support the design and operation of BESS, CSEM is developing a modular battery model based on the physical processes in electrochemical devices. The first step in this investigation consists in developing and running performance (cycling) tests and electrochemical impedance spectroscopy (EIS) measurements at the joint BFH-CSEM Energy Storage Research Center (ESReC) located in Nidau (BE).

Figure 1: Building and some laboratory equipment at BFH-CSEM Energy Storage Research Center (ESReC).

Six cell technologies are under investigation, four of them based on lithium-ion: lithium capacitor (LIC), lithium iron phosphate ($LiFePO_4$), nickel manganese cobalt oxide (NMC), and lithium titanate (LTO), as well as lead-acid and nickel metal hydride (NiMH).

EIS measurements provide the battery impedance as a function of the frequency, which reflects the main processes involved in the battery operation i.e., the charge transfer due to the redox reactions at the surface of the electrodes, diffusion of ions through the electrolytes, and changes to the crystalline structure of electrodes due to ion intercalation. Measurements are performed at different cell temperatures, states of charge and states of health in order to determine the influence of the operating conditions on the battery response.

For performance tests we use a combination of procedures from international standards e.g., IEC 62660-1 and our own. With these tests we can compare technologies with metrics such as the energy density, as shown on Figure 2 for seven electrochemical cells when fully discharged at different ambient temperatures.

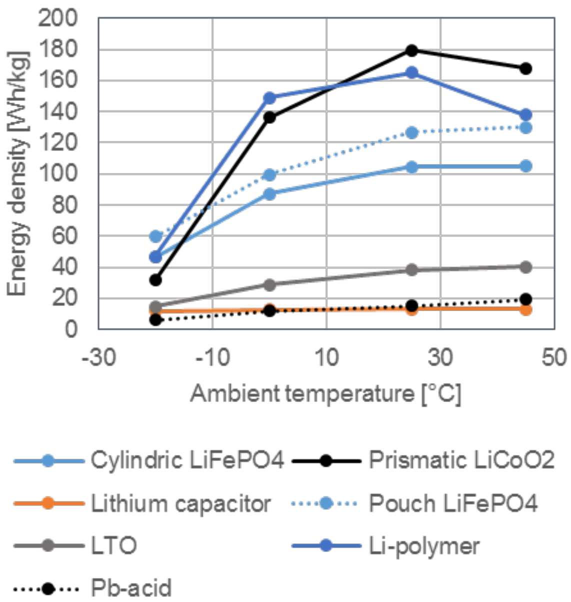

Figure 2: Battery cell energy density as function of ambient temperature.

The model is modular: each block represents a single physical phenomenon. Depending on the application, some dynamics can be neglected. In that case the complete model can be reduced to simplified, lower-order models.

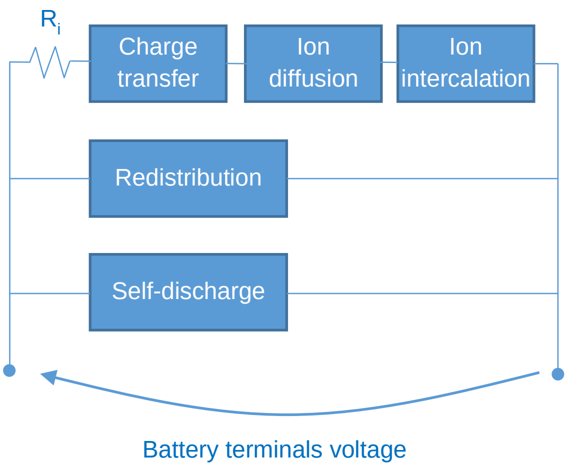

Figure 3: Structure of the dynamic battery model by CSEM.