Advanced Battery Management System Methods for Stationary Storage Applications

Preliminary results from the ISTORMY project

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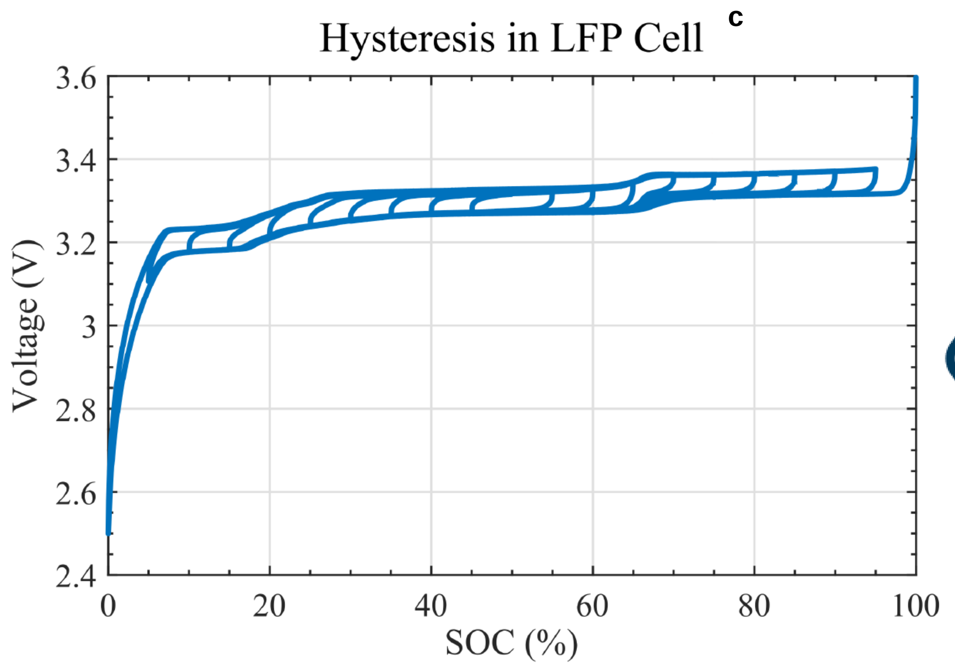
Battery State-of-Charge (SoC) & State-of-Health (SoH)

A **coupled State-of-Charge & State-of-Health** estimation algorithm based on a **Dual Kalman Filter** approach is proposed.

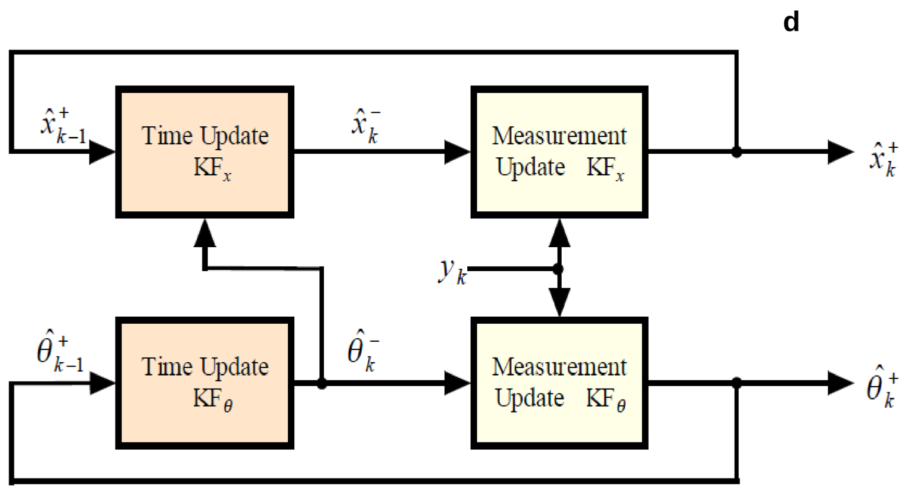
First, performance tests are realized in the laboratory on the LFP and NMC cells that compose the ISTORMY battery pack in order to build two **n-RC equivalent electric circuit** models. A particular focus is made on the characterization of the **hysteresis** phenomenon of the open circuit voltage.



Ageing tests are also performed on the cells to build a semi-empirical **model of capacity loss** that considers both **calendar** and **cycling** degradation mechanisms.

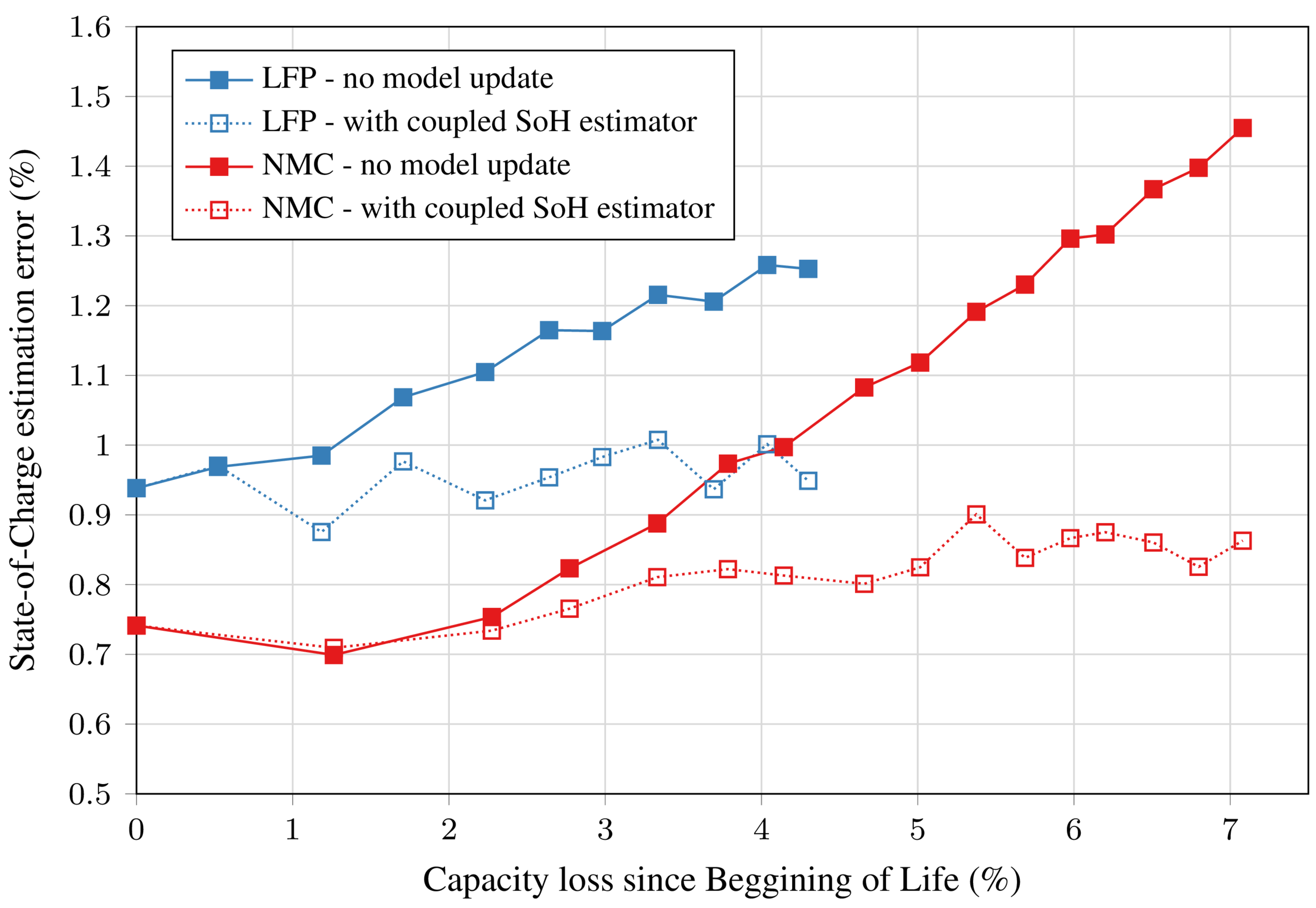
$$dQ_{loss} = \frac{\partial Q_{loss}}{\partial t}\bigg|_{cal} \cdot dt + \frac{\partial Q_{loss}}{\partial Q_{th}}\bigg|_{cyc} \cdot dQ_{th}$$

The State-of-Health estimator makes a **continuous prediction** of the capacity of the battery using the ageing model, and uses the output of the Active Battery Diagnostics as a **periodic observation** of the performance model parameters evolution.



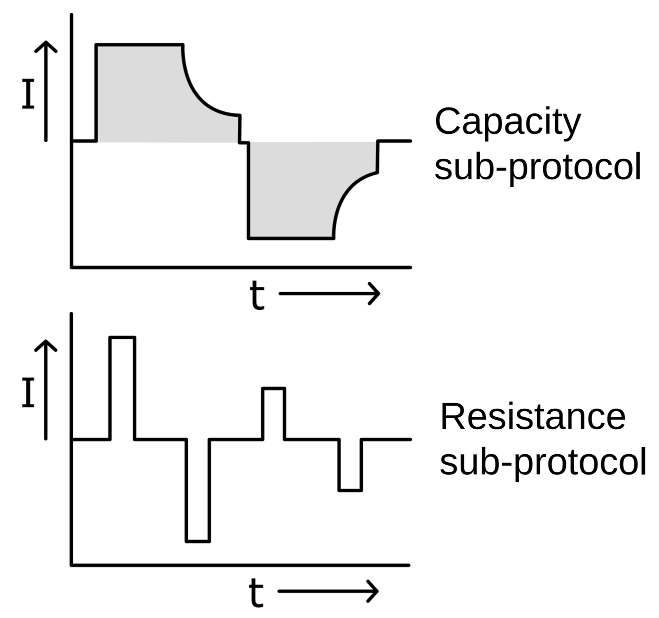
It is important to note that the method can easily **be adapted to any kind of Li ion cell chemistry** (LFP and NMC in this work).

When coupled with the State-of-Health algorithm, the error on State-of-Charge estimation remains **stable along the battery's ageing**. The electrical parameters of the two packs are tracked, providing **precise** and **robust** information to the Energy Management System.

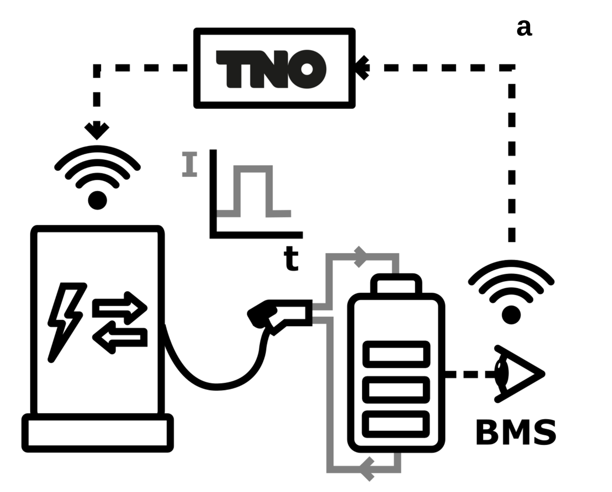


Active Battery Diagnostics (ABD)

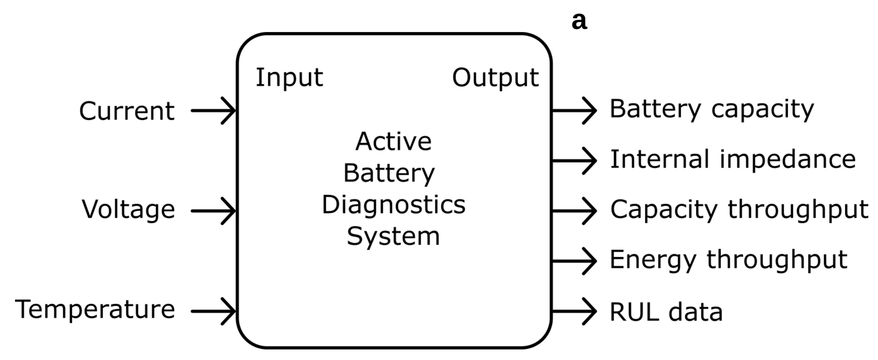
The ABD system actively **diagnoses battery health** of real world applications through manipulation of bi-directional power electronics. The output of the ABD system **feeds up-to-date parameters** to other BMS functions like the SoC, SoH and RUL algorithms, **improving their performance**.



Ideal system to **harvest** high quantity + quality **battery degradation data!**



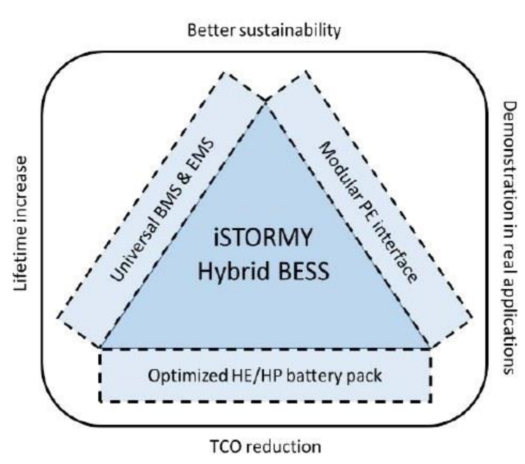
The ABD system measures battery health by applying a specific combination of current waveforms. These waveforms are designed to make **battery health parameters** like capacity and resistance **more accurately measurable**. A trade-off is struck between accuracy, precision and measurement time.



The ABD system provides **high quantities of relevant battery health data** for training of the data-driven battery RUL algorithm (see below).

The iSTORMY Project

The "Interoperable, modular and smart **hybrid** energy storage system for stationary applications" (**ISTORMY**) project is funded by the Horizon 2020 program of the European Union. It presents an innovative **Hybrid Battery Energy Storage System (HBESS)** for grid integration, based on modular conception of the battery pack and power electronics. The goal is to optimize the system to **increase its lifetime** and **reduce the Total Cost of Ownership** (TCO). To that end, the Battery Management System (BMS) offers advanced diagnosis functionalities.



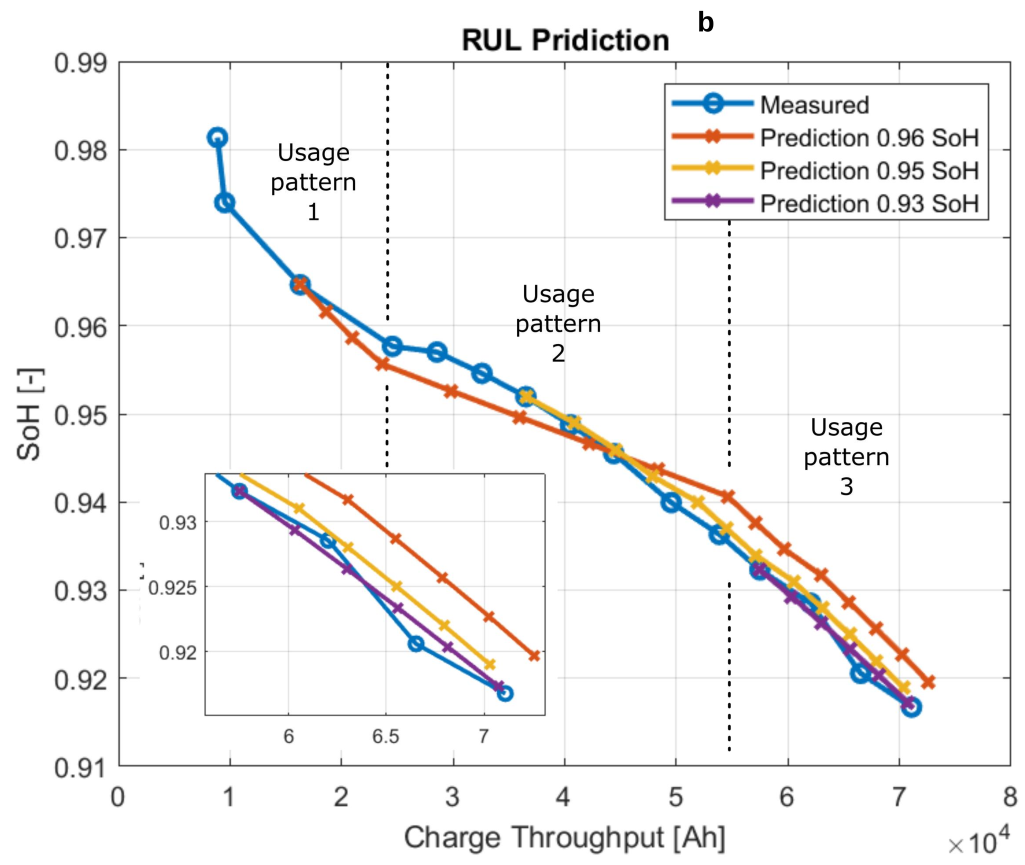
The iSTORMY system uses **multiple different chemistries** of battery cells, combining the strengths of each.

The iSTORMY hybrid energy storage system will be tested at the EDF **micro-grid demonstration** location

Battery Remaining Useful Life (RUL)

A data-driven approach of battery Remaining Useful Life (RUL) estimation is presented, based on **data harvested by the active battery diagnostics**. The current preliminary method uses **support vector regression** in combination with a **compressed historic record** of the battery's usage (including stress factors).

Training data statistics	Laboratory data	Active Battery Diagnostic data
Number of battery cells in data	~ 10-100	> 500
Cost of creating data	€€€	€
Usage pattern of data	Often CC or CCCV 0°C, 25°C or 45°C	Realistic real world use



In the graphic to the left, the RUL algorithm has been trained on data of usage pattern 1 and 3, but not on usage pattern 2. The algorithm visibly struggles with the usage pattern it has not been trained on, yet is able to **correct when retrained on new incoming data.**

Additional training data harvested by the ABD system will likely significantly improve algorithm performance over time.

a Meulenbroeks, T. A. J. "Active Battery Diagnostics for Real World Applications", 2022
b Meulenbroeks, T. A. J. "Battery Remaining Useful Life Estimation Driven by Active Battery Diagnostics", 2022
c Werckle, C. "Improved Equivalent-Circuit model of Lithium-ion Iron Phosphate Cells", 2005
d Plett, G. "Dual and Joint EKF for Simultaneous SoC and SoH estimation", 2004

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