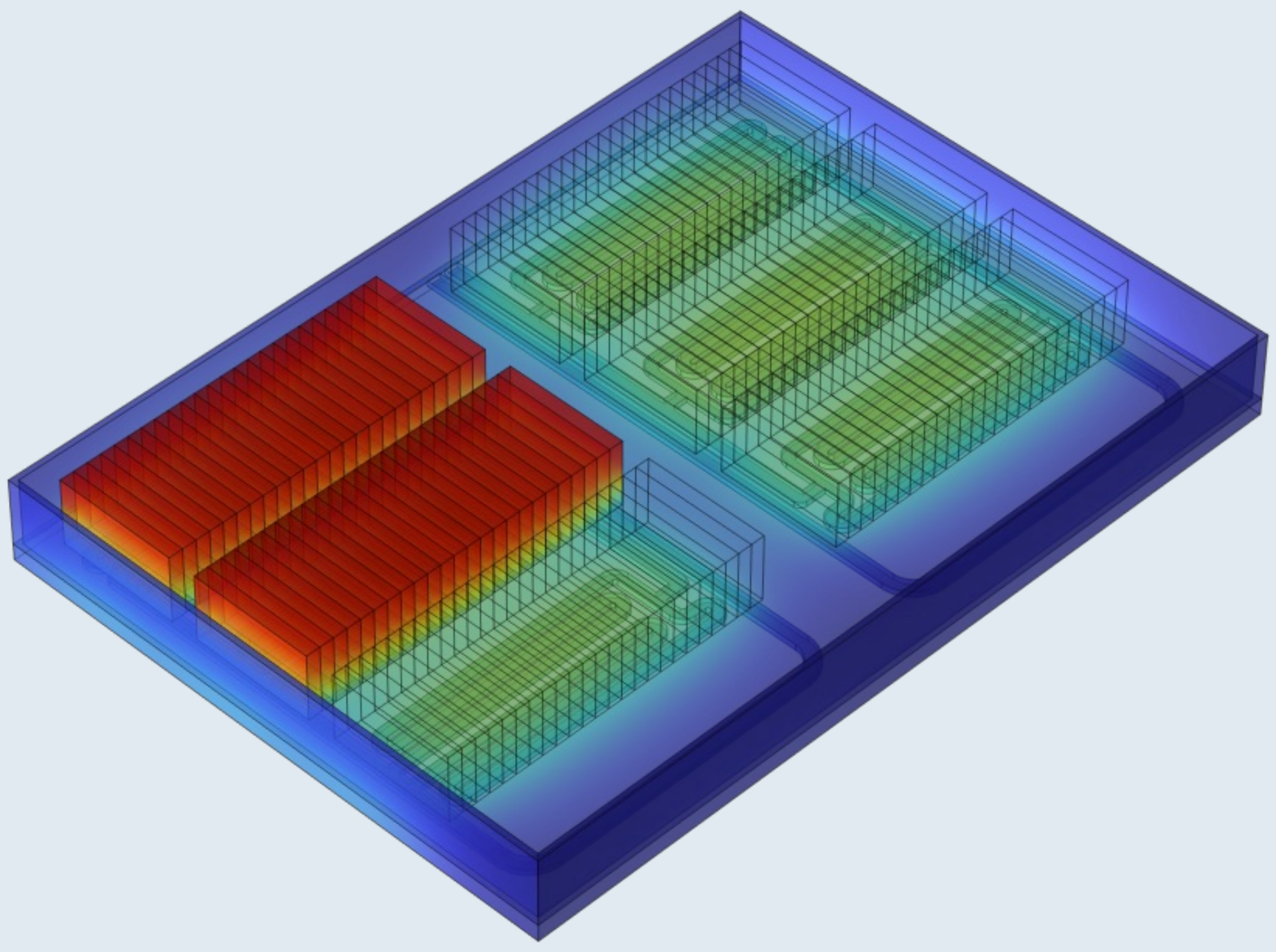


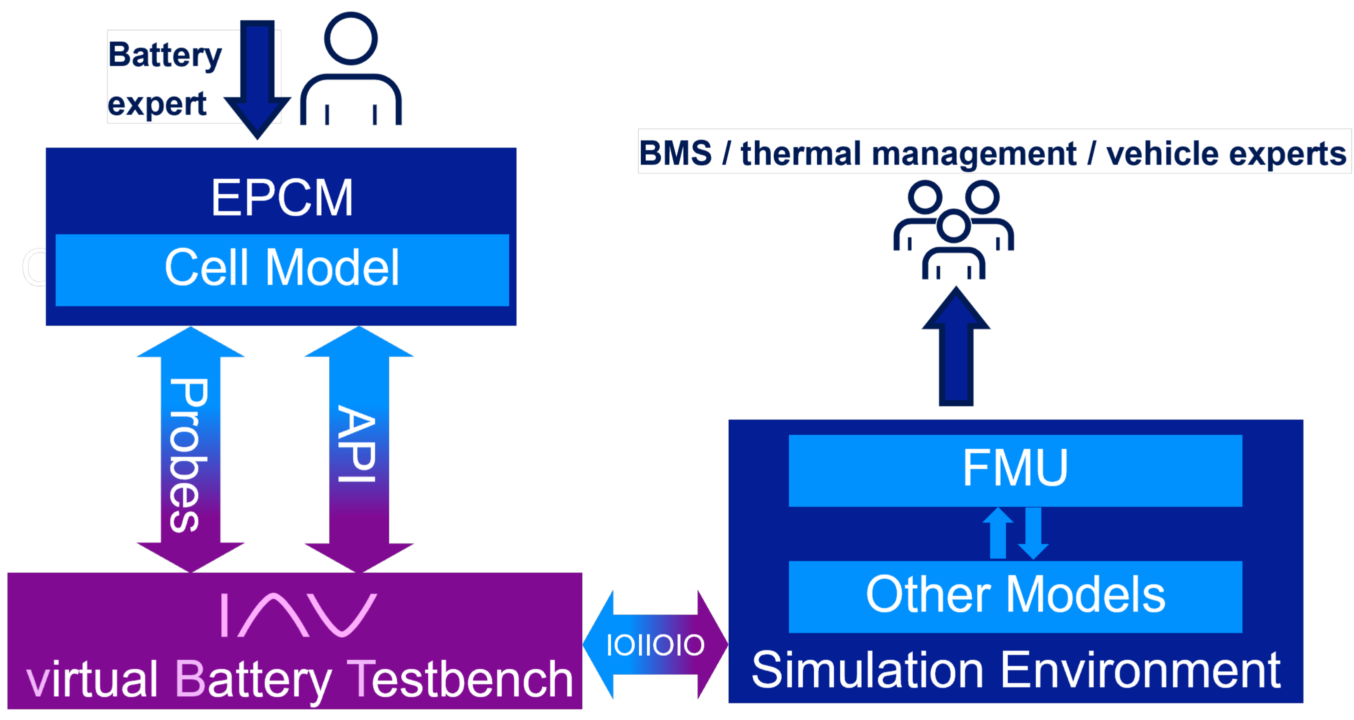
Battery Cell Anomaly Detection via IAV Virtual Battery Testbench based on COMSOL® -API

Development and implementation of a digital twin: Fault detection of cell anomaly with battery management system accessible signals.

J. Werfel, R. Laubenstein, J. Hilgert, M. Kalogirou
Cell, Module & Battery Solutions, IAV GmbH, Berlin, Germany.

Abstract

Battery cell anomalies can indicate an upcoming thermal runaway. Detecting them is crucial to prevent such events. Since there is little data on cell anomalies, reference data must be generated for the calibration of failure detection algorithms. The development of automotive batteries must become faster and cheaper in times of increasing development speed. Therefore, experiments on physical test objects should be reduced to a minimum. In this work, a set of pseudo-2-dimensional cell models created in COMSOL Multiphysics® is coupled with a toolchain for the development of anomaly detection algorithms implemented in SIMULINK®. In this toolchain the battery management system model defines the load scenario, and the cell models provide the required signals, which in turn are used as inputs for the anomaly detection algorithms. This enables the presented track record focusing on anomalies during battery cell operation.



EPCM: Electro-physicochemical model
FMU: Functional Mock-Up Unit
API: Application Programming Interface

Methodology

The digital twin, consisting of 12 or 52 cells (12s1p/52s1p) with a capacity of 78 Ah per cell, is virtually tested with current profiles (idle, driving and charging phases). For one cell (cell 1) a defect is integrated via an internal short circuit resistance (100 Ω).

Additionally, a cell capacity distribution of ±2% and cell film resistance distribution of ±5% was integrated to represent real cell variations which the algorithms should distinguish from defects. The exemplary fault diagnosis methods used consisted of analytical models (recursive least squares, RLS), signal processing (Shannon entropy, SE) and a machine learning method (random forest, RF).

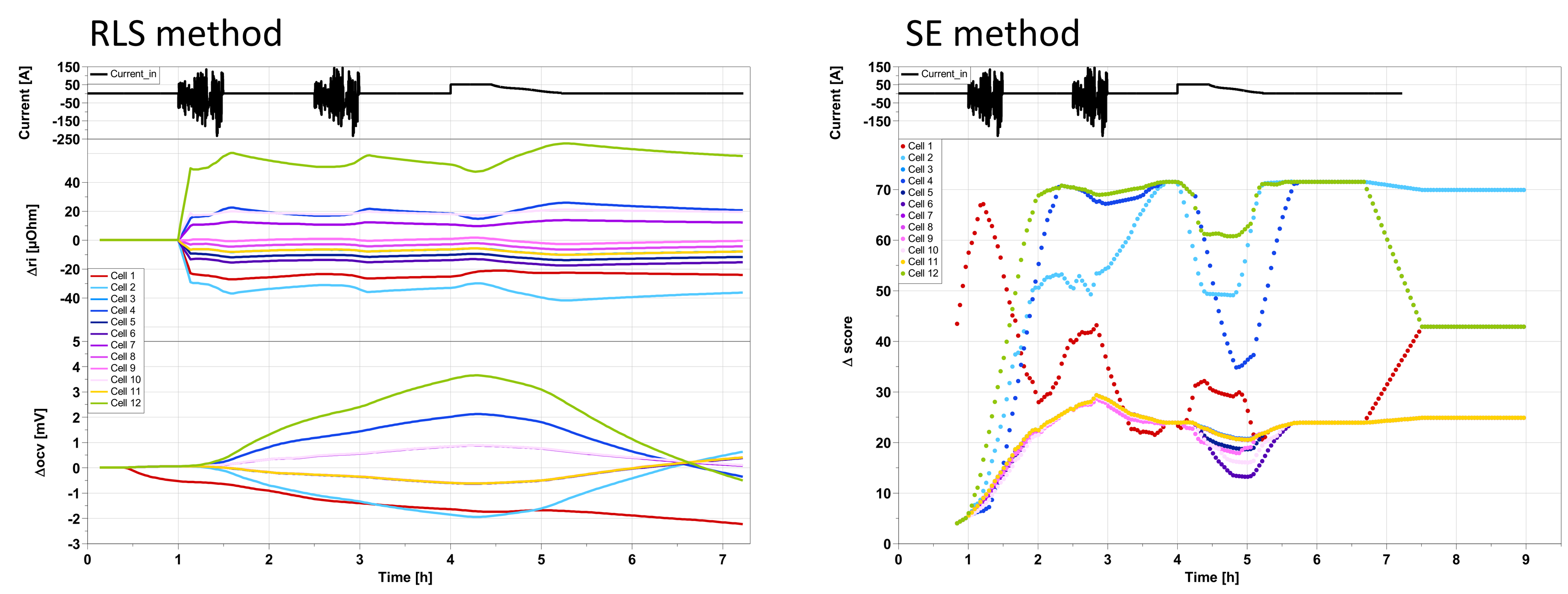
Results

The **RLS method** estimates ΔU_{ocv} and ΔR_i values to minimize the underlying cost function: Cells with very high and low capacity are detected. ΔU_{ocv} allows to detect the faulty cell with continuously decreasing deviation.

For the **SE method**, the faulty cell can be identified during idle phases due to the increasing difference score.

The **RF classification** method mostly classifies the faulty cells with R_{ISC} of 100 Ω and healthy cells with higher R_{ISC} correctly.

IAV's virtual battery testbench allows efficient data usage from high fidelity cell model in different simulation environments for the automative system and function development.



RF classification

State of cell	Healthy	Unhealthy
Accuracy on test samples	80% (4/5)	87.5% (7/8)

FIGURE: Overview of the studied algorithms for the fault diagnosis method with the respective results

REFERENCES

1. R. Laubenstein et al., "Early Detection of Cell Anomaly with BMS-Accessible Signals", *International Battery Seminar*, 2024.
2. Hilgert et al., "IAV's multi-purpose 3D coupling solution for electro-physicochemical Battery models via COMSOL-API", *COMSOL Conference Munich*, 2023.

IAV