Evaluation of the State of Health (SoH) for Second Life Lithium Ion Batteries by Self Learning Algorithms

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SoH of used Batteries

For the second life of EV batteries a classification is necessary to ensure a **safe and efficient second application**. The **SoH** is a meaningful value for the **capacity and permitted power supply** of batteries. State of the art is **a time intensive** cycling and stressing the batteries under **laboratory conditions** (2).

Motivation

- **Fast and easy classification** of batteries from EV for second life applications
- **Analysis of SoH** data of used batteries classify the applications

Cell Tests: IR Drop

Cells with a high (Cell 1) and a low (Cell 2) SoH of the same type are **valuated, aged and tested**

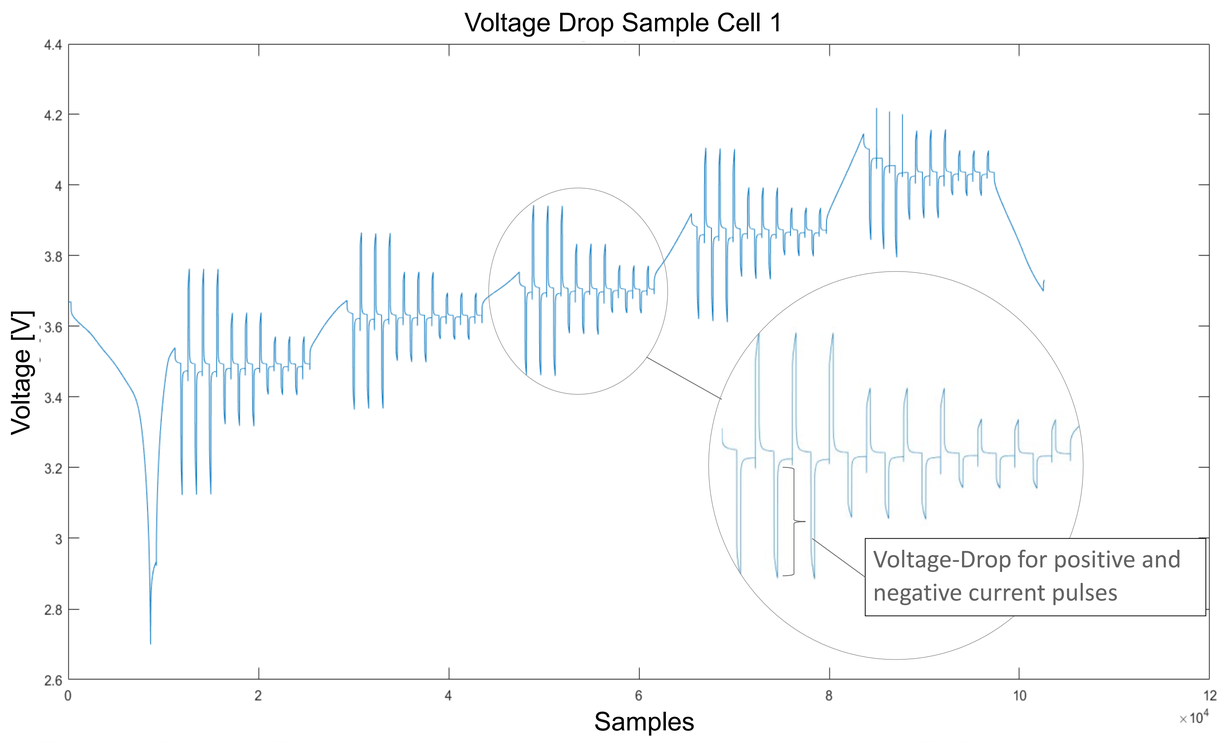
1. SoH determination by the IR-Drop of the **voltage response**
2. Artificial **aging by cycling** the cells (100 times, 1C, 25 °C)
3. Testing phase: Charging and discharging **impulses** with different C-Rates at constant temperature

Supervised Machine Learning

Regressand	Internal Resistance
Transferring Variables (Regressors)	• Current impulse • Relative Voltage Curve • Temperature
Methode	Random Forrest
First Result	The Prediction of the Method fits to 92 % for the collected data

Conclusion

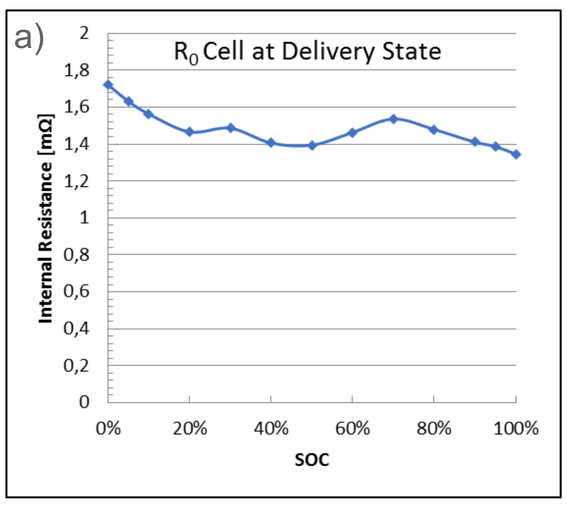
1. The internal resistance is congruent to the SoH
2. Collecting voltage responses to current impulses at different SoC of one battery type
3. Adaptation and transfer of measured data to method of supervised learning machine
4. The prediction of the used method (Random Forest) fits to 92 % for the collected data. Based on this output the method and the data can be optimized for improved results.

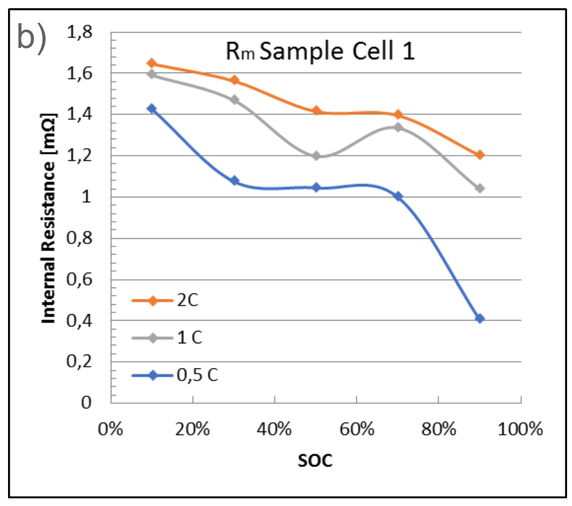


Testing Phase: Determine the internal resistance with an IR-Drop at different SoCs (10 %, 30 %, 50 %, 70 %, 90 %) and different C-Rates

Determining of the SoH on the basis of following formula (1)

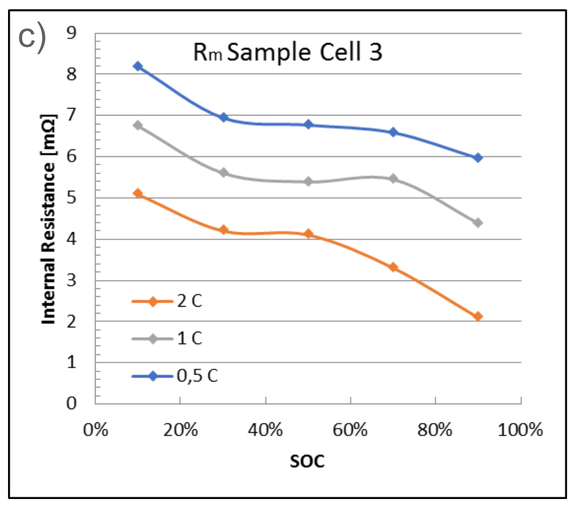
$$SoH_R = \frac{R_0}{R_m}$$

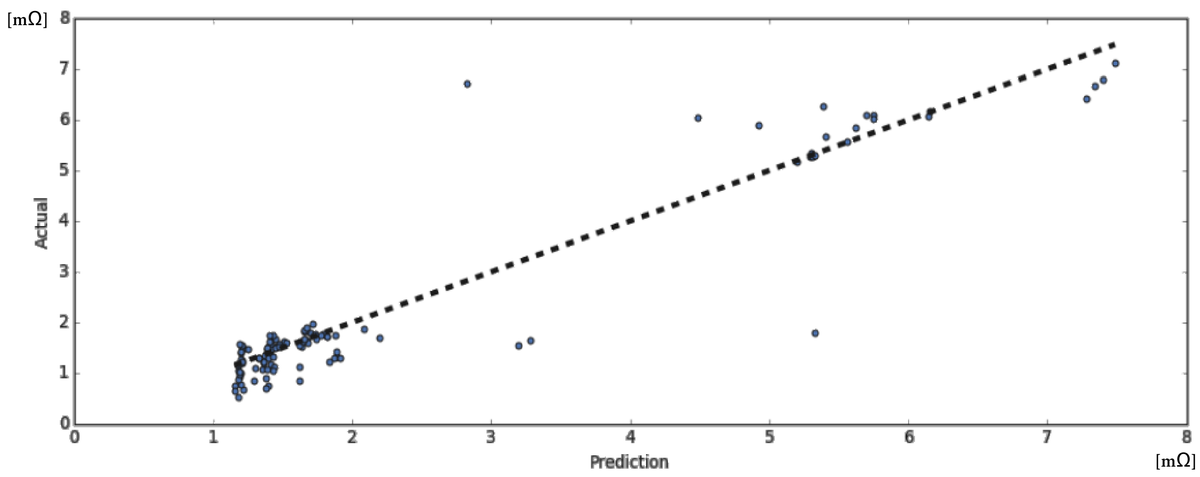




Valuation of the internal resistance for different SoC, Temperatures and C-Rates:

a) Internal Resistance at delivery state at 35 °C (C-Rate: 1 C)
b) Measured internal Resistance, SoH = 100 % at 25 °C (C-Rate:2C, 1C, 0,5C)
c) Measured internal Resistance of an aged cell at 25 °C (C-Rate: 2C, 1C, 0,5C)





Result of the first training and verifying of the supervised machine learning method. Comparison of the actual data and the prediction of the method.

References:

(1) Jossen, A., and Weydanz, W. (2019) Moderne Akkumulatoren richtig einsetzen. 2nd ed.
(2) Sebastian Fischhaber, Forschungsstelle für Energiewirtschaft (FfE) e. V. Studie: Second-Life-Konzepte für Lithium-Ionen-Batterien aus Elektrofahrzeugen. Analyse von Nachnutzungsanwendungen, ökonomischen und ökologischen Potenzialen

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