Impedance Spectroscopy as a Battery State-Of-Health Indicator

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Introduction

Electromobility Institute

@ Bochum University of Applied Sciences (HS-Bochum)

The Institute has

3 Professors and
27 Research Assistants

Research involves Electric and Hybrid-Electric Transportation, examples:

SolarCar – Solar Electric Vehicles
Competition Vehicle fully developed at HS-Bochum

BOmobil – Electric Small Transporter
cooperation with several large firms in the Automobile Industry to develop a bottom-up electric car, Goal: 10 000 per year series ready.

BatMan-Project

Two parts:

- Series Production ready **Battery Management System** for Electric Vehicles.

- Researching Battery **State-of-Health** indications

Researchers

- Mattias Tjus, M.Sc.E.
- Prof. W. Ritschel, Prof. J. Albers, Project leaders
- B.E. Manuel Berg, Student researcher
- Dipl.-Ing. N. Stentenbach, Scientific Advisor
- Prof. B.-E. Mellander, Scientific Advisor, Chalmers TH, Sweden

Background Theory

Batteries

Demands on Capabilities of EV Batteries
(approximate figures by the author)

- Enough capacity for Most Daily Travels (eg. 200km/day, ca 40kWh)
- Practical Weight (eg. complete EV-drive train mass = mass of a standard engine, gears and gasoline tank, below 500kg)
- Charge over night and Fast Charge capability (8h 100%, 30min 80%)

Lithium Ion Batteries

.. make this possible!

Panasonic NCR18650A
A123 20Ah

	Energy Density Optimized (eg. Laptop-cells)	Power Density Optimized (eg. Power tool-cells)
	250Wh/kg	115Wh/kg
	500w/kg	2 400W/kg
	40kWh ~ 160kg	350kg
	160kg ~ 80kW	350kg ~ 840kW
	45 min Fast Charge	10 min Fast Charge

Impedance Spectroscopy

Frequency dependant Impedance

Cell properties influence complex impedance.
Real impedance, resistance: connections, electrolyte
Complex Impedance: Cathode and Anode geometry, ion diffusion

Electrochemical Impedance Spectroscopy

- Send a known signal over a load (Battery) and measure the response.

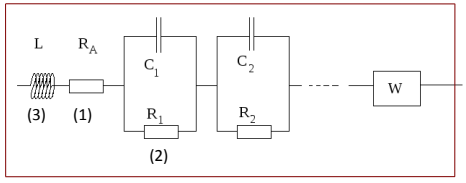
Comparing impedance plots (Nyquist Diagrams) considering regular electronics parts, as resistors and capacitors, with a Battery, some approximations can be deduced: (next slide)

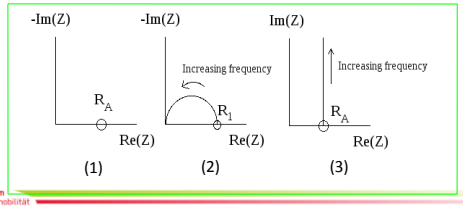
Impedance Spectroscopy

(1) $Z_A = R_A$.

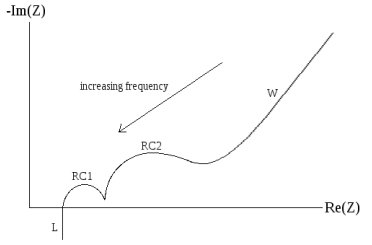
(2) $Z_1 = (R_1^{-1} + j\omega \cdot C_1)^{-1}$.

(3) $Z_L = j\omega \cdot L$.





Impedance Spectroscopy

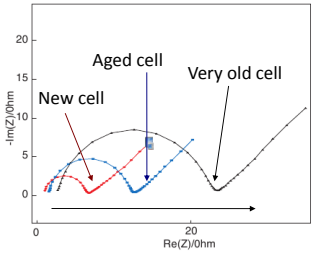


Idea

What about the State-of-Health?

The impedance values change with age!

Resistance increase, shifting the plot to the right:



[Alidissi]

SOH = ?

By knowing the changes to the impedance values

and at the same time measuring the remaining capacity

- a method can be constructed to estimate SoH

without measuring the capacity directly!

Practical Idea

And in Practise?

Electrochemical Impedance Spectroscopy

... can be done manually using a function generator and an oscilloscopy, but, using a Data Acquisition card can potentially be used for systematic use:

MyDAQ

... a National Instruments MyDAQ instrument is currently studied to achieve the wanted functions;
- Function generation (programmable analog output)
- Impedance measurement (analog input)
- Easy-to-use computer interface

Problem

... A bridge will most likely be needed to allow the instrument to work with the very low impedance of a large lithium ion battery (milliohms)

And in Practise?

MyDAQ

Thank You

Questions

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