Battery Impedance Mapping and Characterization

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EECOMOBILITY (ORF) & HEVPD&D CREATE

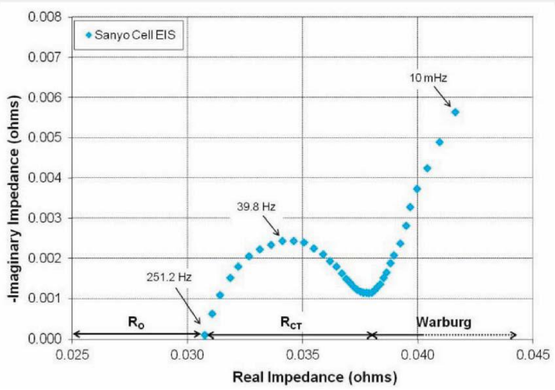
D&V Electronics Cell Tester

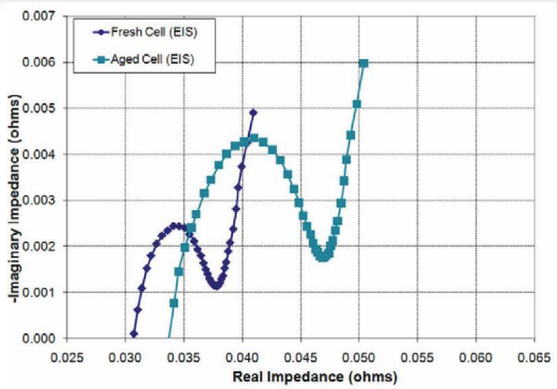
D&V Electronics has developed a unique cell tester that enables EIS, drive cycle and columbic efficiency testing and characterization. The tester is able to switch between three different test modules, including a high frequency signal module. This integration allows the tester to streamline the testing procedure and provide better estimates for state of health (SoH) and state of charge (SoC).

Module	Applications	Hardware Highlights
High Power	• Load / energy source • Drive cycle profiles • SOC-OCV curves	• Max. Current: 100 A • +/- 0.02% FSR • Supports parallel connection
High Frequency	• EIS testing	• 0kHz – 50kHz • +/- 0.02% FSR • Sampling: 200kHz
High Accuracy	• Coulombic efficiency measurements	• Accuracy: 10 ppm

"D&V Electronics." BCT Series - Battery Cell Testers: BCT-150, www.dvelectronics.com/products/electric-powertrain-battery-testers/product-capabilities/specialty/bct-150-battery-cell-tester.html.

Electrochemical Impedance Spectroscopy (EIS) Testing

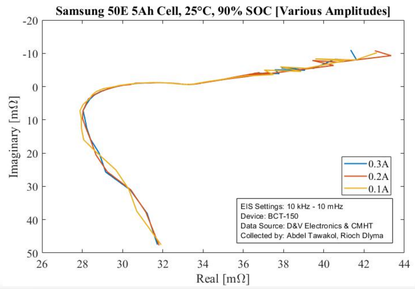




Christophersen et al. (2012). Rapid Impedance Spectrum Measurements for State-of-Health Assessment of Energy Storage Devices. SAE International Journal of Passenger Cars - Electronic and Electrical Systems. 5. 246-256. 10.4271/2012-01-0657.

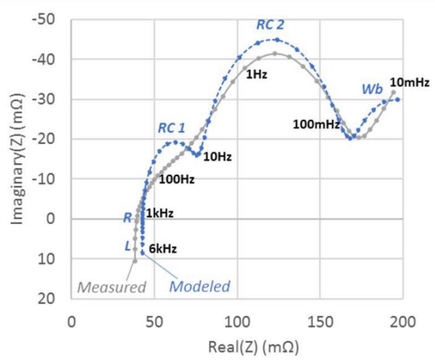
- Electrical impedance is a measure of a circuit's ability to resist current flow
- Although it is similar to resistance, it is more useful to use impedance in real-world applications that demonstrate much more complex properties
- Using Electrochemical Impedance Spectroscopy (EIS) testing allows us to examine the dynamic characteristics of the battery
- This is usually done by applying an input current waveform to 'excite' an electrochemical cell, and then measuring the voltage response
- EIS can tell us important information about the health of the cell and the chemical processes involved. It can help us understand where cell degradation is occurring and how aging affects the performance of the cell

Research Project

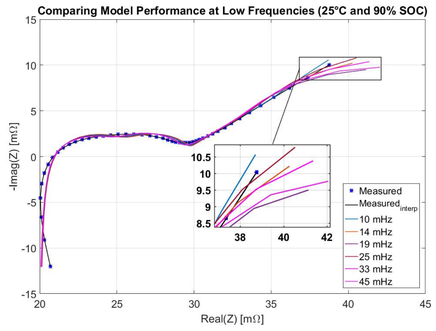


- This research will consider battery performance under various operating conditions pertaining to SoC, aging, and temperature
- Looking at analyzing impedance characterization and trying to understand how the battery is affected under those different operating conditions
- EIS test data will be correlated to a range of impedance models that are covered in literature
- D&V Electronics' unique battery cell tester will be used for this research
- As part of this research, the functionality of the tester will be refined
- This refinement will include: validating the performance and safety operational limits, as well as making software updates and implementing new features based on user feedback

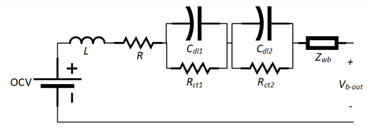
EIS Fitting at Low Temperatures Using Constant Phase Elements



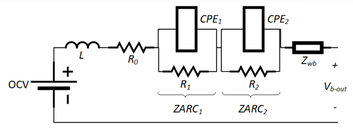
Example model fit to EIS measurements at -10°C and 80% SOC [1]



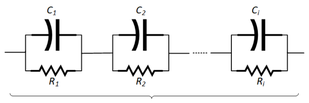
Demonstration of the effect on model accuracy when removing low frequency data points



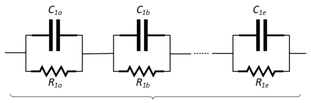
Example equivalent circuit model used for EIS fitting [1]



Proposed equivalent circuit model using CPEs



Warburg impedance element [1]



ZARC element

- Two important considerations in battery research are battery modelling as well as battery testing and characterization
- Battery modelling provides an understanding of how batteries behave under given conditions and their potential performance in specific applications
- Battery testing and characterization can require precise and highly developed equipment, depending on the test procedures involved
- EIS testing in particular can be time consuming and involve intricate planning (especially at lower frequencies)
- EIS results at low temperatures can be improved by using low frequencies, to better capture the diffusion process that occurs at a very slow rate
- Battery impedance models can be refined using various equivalent circuit elements to provide a more complete representation of EIS data
- One technique discussed in literature to address diffusion behaviour is the use of constant phase elements (CPEs)
- Using ZARC elements comprised of CPE and resistance pairs to capture mid-frequency impedance values has shown promising results, with room for improvement
- The D&V Electronics cell tester is being used to collect low frequency data for this study

[1] P. Kollmeyer, A. Hackl and A. Emadi, "Li-ion battery model performance for automotive drive cycles with current pulse and EIS parameterization," 2017 IEEE Transportation Electrification Conference and Expo (ITEC), Chicago, IL, 2017, pp. 486-492.

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