Drift Correction in EIS

Introduction

Electrochemical Impedance Spectroscopy (EIS) is a powerful technique for understanding the physical and electrochemical properties of electrochemical reactions. The central pillars of valid EIS results are linearity, causality and stability. In practice, stability for pseudo steady state electrochemical systems is difficult to achieve especially at low frequencies where the voltage (or current) may change is a systematic way or drift. This leads to results that are difficult to interpret or have noise.

One method of handling drift is to apply an algorithm to the data collection that corrects for the drift. Gamry has developed a proprietary method for correcting this drift.

Implementation in the Gamry Framework

Drift correction has been added to the EIS experiments in the Gamry Framework, starting with software release version 7.8.4. The drift correction algorithm is implemented in every single sine EIS experimental script, whether as part of the Framework or the Sequence Wizard, as a radio button that can be switched on or off.

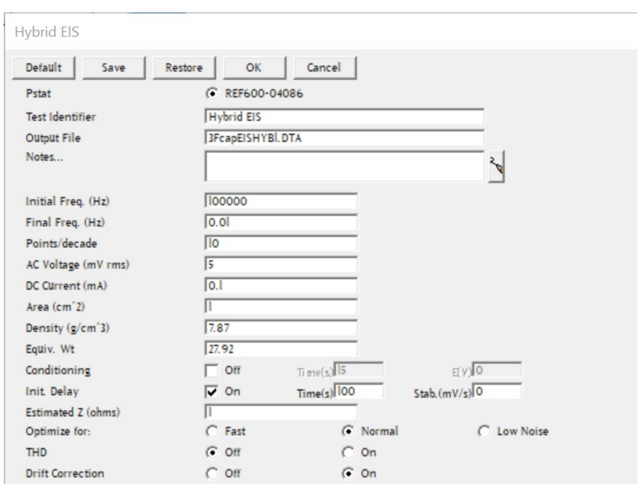

Figure 1: Setup Page for Hybrid EIS

The setup page shown for the Hybrid EIS experiment has all the same parameters as before with the addition of the selection for Drift Correction at the bottom of the page. The location of the selection is the same for other EIS experiments. If Drift Correction is turned on, the Framework acquisition program records both corrected and uncorrected data for comparison purposes.

The types of sample where drift correction may have an impact are energy storage devices like batteries, supercapacitors and fuel cells as well as in corrosion experiments where the corroding sample may change as the corrosion products build up.

3F Commercial Supercapacitor

Impedance measurements were recorded on a 3F commercial supercapacitor in a partially charged state. The rated maximum voltage of the capacitor was 2.7V. Drift was induced by making galvanostatic measurements with a small offset DC current which slowly charged the capacitor.

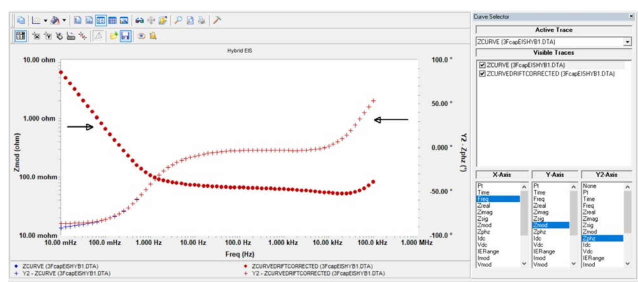

Figure 2. Curve Selector (right) showing both Corrected and Uncorrected Data Sets.

The effect of this DC current on the impedance data can be seen in both the Bode plot in Figure 2 and more clearly in the Nyquist plot in Figure 3. The blue points are the uncorrected data and the red points are the corrected data. Note that the either data set can be hidden using the Curve Selector as shown in Figure 2.

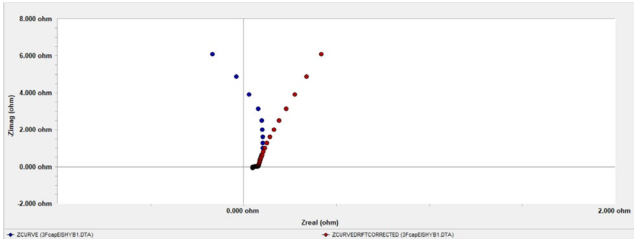

Figure 3. Overlay of Corrected and Uncorrected Data for 3F Supercapacitor (Nyquist) Blue (Uncorrected), Red (Corrected)

The corrected data was compared to an independent potentiostatic EIS experiment on the same supercapacitor at a similar voltage. Figure 4 shows the overlay of the data in the Nyquist plot. There are some small differences, but the data appear to be consistent.

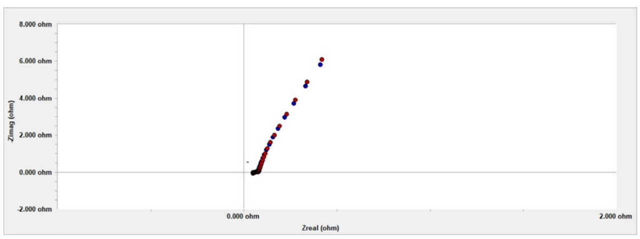

Figure 4. Overlay of Corrected Data and Potentiostatic EIS data at a similar voltage.

18650 Lithium Ion Battery

Lithium ion batteries also drift at low frequencies due to internal effects in the battery like self-discharge. As in the case of the supercapacitor, drift was induced by applying a small DC discharge current during the galvanostatic EIS experiment. This current had its largest effect at low frequencies and hence the most significant amount of correction is seen at the lowest frequencies. Figure 6 shows clearly the correction applied has a significant effect on the data on the right-hand side of the plot.

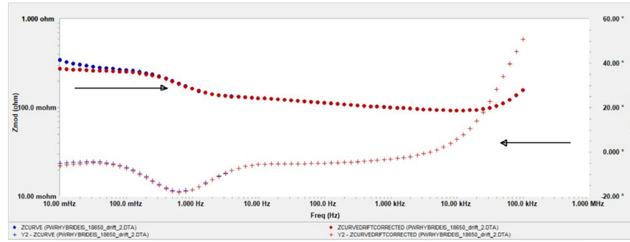

Figure 5. Overlay of Corrected and Uncorrected Data for an 18650 Lithium Ion Battery. Blue (Uncorrected), Red (Corrected)

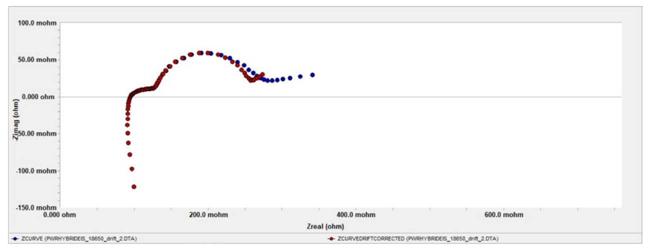

Figure 6. Nyquist Plot of Data from Figure 5. Blue (Uncorrected), Red (Corrected)

Conclusion

Measurements on batteries and supercapacitors with induced drift show that the drift correction algorithm successfully corrects the data to yield results similar to the results where little or no drift is seen. While drift correction is useful to help visualize drifting samples, caution should be exercised in the interpretation of results as real world samples drift.

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