Demonstration Guide

analytical measurement solutions

AC / DC cell analysis techniques; Comparison of multi-sine / FFT and single sine correlation

John Harper and Brian Sayers
Solartron Analytical, Farnborough, UK.

Demonstration Expt: DG08

Introduction

The Solartron CellTest System offers the capability of measuring cell impedance using multi-sine / FFT or single sine correlation (SSC) techniques. Both techniques have advantages and disadvantages and therefore it is for the end user to decide which technique is appropriate for use in their application. To summarize the techniques;

i) SSC is widely regarded as the most accurate and repeatable method of measuring the impedance of a cell. If an appropriate integration period is selected, the noise rejection capabilities of the technique are unparalleled. However, since the cell under investigation is stimulated sequentially at different frequencies over the range of interest, experiments can take in excess of one hour (particularly if low frequency analysis is required). Whilst this may be a trivial issue if the cell chemistry is constant during the measurement. However, there are applications where this may not be the case and interpretation of low frequency results must therefore be treated with care. In addition, sometimes a large throughput of tests are required on multiple cells which may take too long when using the SSC technique.

ii) Multi-sine / FFT techniques apply multiple sinewave frequencies simultaneously to the cell throughout the frequency range of interest. For example, three frequency decades may be selected with a base frequency of 1mHz providing simultaneous impedance results for 1Hz to 1mHz in a single measurement which would take around 16 minutes to complete. By comparison, a similar SSC analysis would take approximately 80 minutes, (five times as long). The major disadvantage of the multi-sine technique is that rejection of noise and distortion is not as effective as in SSC. However, this may be a small price to pay when the scientist needs fast measurement capability particularly at low frequencies and when the test cell may not be stable for prolonged periods.

The following demonstration compares the two impedance analysis techniques.

Equipment

- Solartron CellTest system comprising one 1470E multi-channel potentiostat, one 1455 FRA
- battery demonstration test box

Connections

Connect the coloured cables from 1470E channel 1 to their corresponding coloured connections on the battery test box. Ensure that the FRA connection of the main channel of the 1470E Tester is connected to the main channel connection of the 1455 FRA.

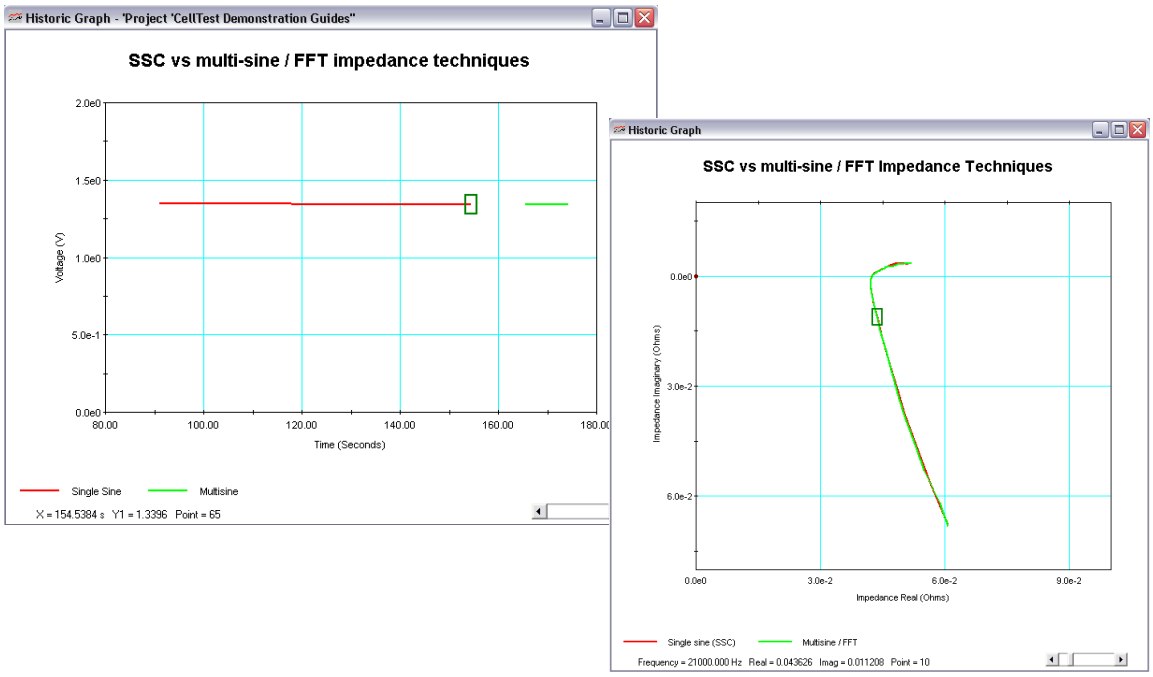
Software Setup

Using the experimental setup described in the table below, it is relatively simple to demonstrate the use of both single sine correlation and multi-sine / FFT techniques to measure the impedance of the battery. The battery was charged once prior to the two impedance measurements so that it was in the same state of charge in both cases.
The impedance techniques can be run in current (gstat) or voltage (pstat) control mode as preferred. The AC stimulus level was chosen to be well within the linear regime of the AA cell (100mA AC produced less than 10mV AC). By examining the results in tabular format, it can be seen that the voltage stimulus level per frequency in the multi-sine / FFT analysis was much lower than the single sine stimulus and, with care, could have been increased to further reduce noise.

Schedule

Step	Parameter	Setting	Comment
Step 1 Normal Step	i) Current control ii) Sample Rate iii) Step duration	i) +0.5A ii) 1 sample / second iii) 60s	charge battery, slow data capture
Step 2 Rest Step	i) Sample Rate ii) Step duration	i) 1 sample / second ii) 30 seconds	Allow cell to rest after charge, slow data capture
Step 3 SSC Imped-ance	i) Mode ii) DC level ii) AC level ii) Measurement mode iii) Frequency range	i) Current control ii) 0A ii) 100mA iii) Sweep frequency iii) 100kHz to 1Hz 10 pts / decade Log sweep	- SSC impedance method - Impedance measurement at zero DC current (same as open circuit potential) - Current (gstat) control is used here, though voltage (pstat) mode can be used if preferred
Step 4 Rest step	i) Sample Rate ii) Step duration	i) 1 sample / second ii) 10s	Allow cell to rest, slow data capture
Step 5 multi-sine / FFT imped-ance	i) Mode ii) DC level iii) AC level iv) Measurement mode v) Minimum frequency vi) stimulated frequencies	i) Current control ii) 0A iii) 100mA iv) Multi-sine / FFT v) 1Hz, 5 decades vi) custom frequency	- Multi-sine / FFT method using default frequency list. - Impedance measurement at zero DC current (same as open circuit potential) from 100kHz to 1Hz (5 decades) - Current (gstat) control is used here, though voltage (pstat) mode can be used if preferred

Results



The single sine measurement is presented in red, multi-sine / FFT in green on the above plots. The impedance results are very similar although there is a little more noise associated with the multi-sine / FFT measurement, which is to be expected. The speed of multi-sine / FFT when compared with single sine is clearly shown on the time graph. Indeed, the measurement time was less than one fifth of that of the equivalent SSC measurement.

Conclusions

Each technique has its relative merits. If the speed of measurement is critical then the use of multi-sine / FFT technique is recommended. If however, the user requires the highest quality, noise free results then it is more appropriate to use single sine correlation.