Demonstration Guide

analytical measurement solutions

solartron analytical

AC / DC cell analysis techniques; State of charge investigation

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

Demonstration Guide: DG02

Introduction

The use of impedance measurements to determine the state of charge of a battery is well known. Tests are often run to determine the battery impedance in its fully charged, partially charged and fully discharged state. Impedance measurements not only give information about the state of charge of a cell but also gives a lot of information about the cell's state of health. Failure modes can be identified well before actual failure takes place by examining the trend of impedance after various numbers of charge / discharge cycles.

The following experiment is easy to set up and can be customized by the user in many ways, for example:

- If impedance is to be checked as a function of the number of charge / dicharge cycles run on a particular cell, this can easily be done by adding a repeat loop to the sequence below.
- Impedance tests can be run on fuel cells at various load currents. In this case only the discharge part of the sequence is used and a DC current is entered in the DC settings of the impedance step. Impedance can be checked at different DC current loading levels by adding more impedance steps into the sequence, each with different DC current load setting.
- Alternatively, additional discharge and impedance steps may be added to break up the discharge process into segments, allowing a detailed impedance vs state of discharge map to be built for a particular cell. This gives a great deal of information about how various cells compare during the discharge process.

The CellTest system is totally flexible and can be used to run virtually any impedance test that can be imagined especially now that independent frequency response analyzers (FRAs) can be connected for each channel.

Equipment

- Solartron CellTest System (comprising of a 1470E multi-channel potentiostat and a 1455 FRA)
- battery demonstration test box

Connections

Connect channel 1 to the battery demonstration box using the colour coded leads.

Software Setup

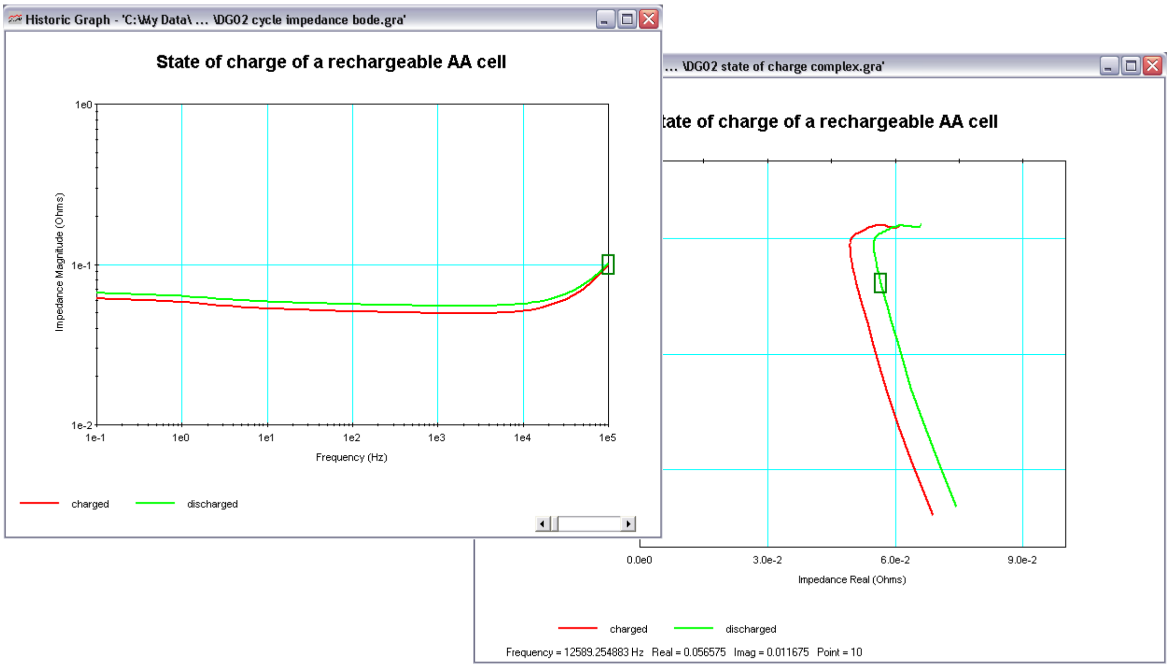
Using the experimental setups described in the tables below, it is relatively simple to demonstrate the use of impedance for analyzing the state of charge of primary (single use) or secondary (re-chargeable cells). In the case of primary cells or fuel cells, of course, the charge step should be removed from the sequence.

The cell is only partially charged and discharged to keep the time duration of the demonstration to a reasonably short period. In practice, charge and discharge times would be much longer and at higher rate, which would more appreciably change the state of charge of the cell.

Schedule

Step	Parameter	Setting	Comment
Step 1 Normal Step	i) Mode ii) Start level ii) Sample rate iii) Step duration	i) Current control ii) +1A iii) 1 sample / second iii) 2 minutes	charge the cell - 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 Impedance	i) Mode ii) DC level iii) Channel selection iv) AC level v) Measurement mode vi) Frequency	i) Voltage control ii) 0V relative to previous iii) Main channel only iv) 10mV v) Sweep frequency vi) 100,000Hz to 1Hz Logarithmic sweep 10 pts / decade	Impedance sweep from 100kHz to 1Hz measuring main and auxiliary channels.
Step 4 Same as step 1 except:	ii) start level	ii) -1A	partially discharge the cell
Step 5	Same as step 2		
Step 6	Same as step 3		

Results



The impedance of the cell when charged and discharged are shown above in Bode and complex plane format (graph format can be selected by right clicking on the graph and changing the graph type in the setup menu). The cell is clearly higher impedance when discharged than when it is charged (there is a 10% difference in cell impedance even on this very short duration partial discharge test) and it can therefore be seen that impedance can readily be used as an indicator of state of charge of the cell. Additional cell "state of health" information is also available from detailed analysis of the shape of the curve.

Conclusions

Impedance measurements may be used to determine the state of charge and state of health of a cell (whether it is a single-use or rechargeable cell) and this provides essential information to the engineer or scientist regarding mechanisms that are critical toward the development and realization of emerging technologies.