ModuLab®
electrochemistry

Application Guide

EIS cell analysis techniques
Characterisation of individual cells within energy storage devices using auxiliary electrodes

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

Application Guide: AGML03

Introduction

Energy storage devices such as fuel cells and batteries are usually constructed from multiple cells that are connected to form a stack. The characterization of many processes within the stack can be determined using impedance spectroscopy and this is achieved by connecting the cables from an electrochemical test system across the entire stack via the terminals on the cell. However, this method cannot determine the impedance of individual anodes and cathodes or even individual cells within the stack since it measures the combined impedance of all cells. Diagnosis of failure mechanisms within the stack is usually determined by disassembly of the cell; a time consuming and often unnecessary process. Indeed, visual inspection of the components cannot always help to deduce the mode of failure. Examples include poisoning of catalysts and hydration effects in fuel cell membranes.
With the addition of the auxiliary voltage measurement option, the Solartron ModuLab System provides measurement of the individual DC voltage drop and impedance of anodes, cathodes and cells within the stack which can identify the cause of a problem without the need to dismantle the cell. This demonstration guide shows how to configure the system to allow auxiliary DC voltage and impedance measurements across lead acid batteries connected in series in the form of a stack. This technique may easily be applied to multiple cells and electrodes.

Key system capabilities used in this demonstration

- Auxiliary voltage DC voltage drop and impedance measurements
- High voltage option for testing battery and fuel cell stacks (up to 100 V)
- Internal / external booster options for higher current (up to 25 A)

Equipment required for this demonstration

- ModuLab electrochemical test system with Booster 2A and HV options (experiment may be run at lower voltage / current if ModuLab potentiostat only is available)
- Two sealed lead acid batteries - e.g. 6 V or 12 V (for example 2.5 Ah)

Connections

- Connect the batteries in series (black terminal from one battery to the red terminal on the other)
- Connect as shown in the connection diagram in the software with auxiliaries across individual cells.

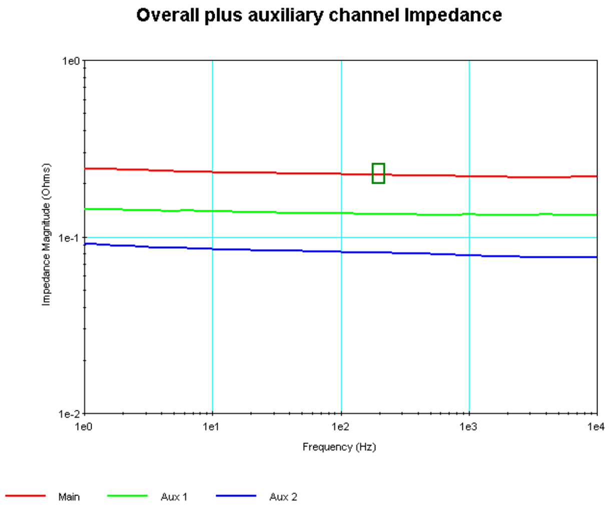
Experiment setup

Select "AGML03 Fuel Cell Stack Tests" in the "ModuLab Demonstration Guide" project

Step #	Purpose
Step 1	Charge the battery using galvanostatic mode - slow data capture. examine voltage drop from each cell in the stack via the auxiliary voltage inputs
Step 2	Allow cell to rest after charge - slow data capture, monitor each cell
Step 3	Impedance sweep from 100 kHz to 1 Hz measuring main (overall stack impedance) and auxiliary channels (impedance of individual cells)
Additional test possibilities: • Loops could be used to repeat the entire sequence for cell lifetime tests	

Notes on setup

Using the experimental setups described in the table above, it is relatively simple to demonstrate the use of auxiliary voltage channels to measure the DC voltage and impedance measured from individual cells in the stack arrangement. Similar techniques may be used to measure battery and fuel cell stacks of up to 100 V DC. ModuLab provides measurements on four auxiliary channels and the auxiliary channels on the high voltage option are also able to measure up to ±100 V.
For battery / fuel cell stacks with a greater number of cells than four, the auxiliary channels may be connected via a multiplexer (for example a Keithley 7001 fitted with 7011 multiplexer cards). The cells in the stack may then be measured four at a time by switching auxiliary channel connections via the multiplexer. In this way configurations may be used that provide measurements with virtually unlimited number of cells in the stack.



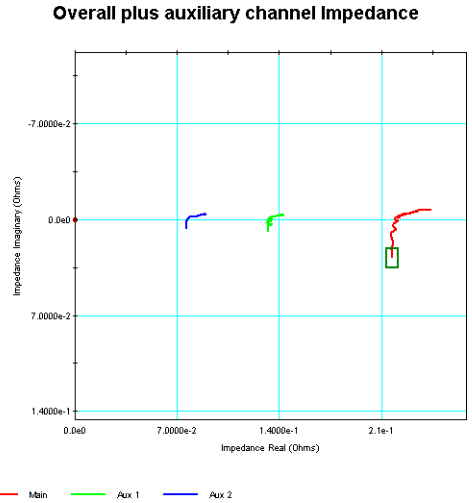


Figure 1: Analysis of individual cells within a stack

Data presentation and analysis

The impedance of the individual cells (green and blue lines) and total impedance of the stack are shown above in Bode and complex plane format. This can easily be extended to many more cells in a larger stack. The DC voltage measurements of individual cells and the complete stack and the current through the stack may also be displayed.

Conclusions

The ability to measure the impedance of individual cells within a stack arrangement allows the engineer or scientist unparalled access to significant information of mechanisms that are critical toward the development and realization of emerging energy technologies.

Application Guide

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UNIT B1 ARMSTRONG MALL
SOUTHWOOD BUSINESS PARK
FARNBOROUGH, GU14 0NR
UNITED KINGDOM
Phone: +44 (0) 1252 556 800
Fax: +44 (0) 1252 556 899

801 SOUTH ILLINOIS AVENUE
OAK RIDGE
TN 37831-2011
USA
Phone: +1 865 425 1360
Fax: +1 865 425 1334

Visit our website for a complete list of our global offices and authorized agents

solartron.info@ametek.com www.solartronanalytical.com

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