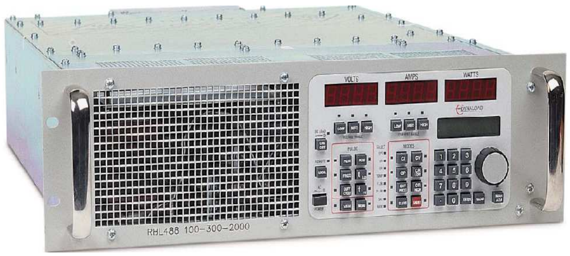
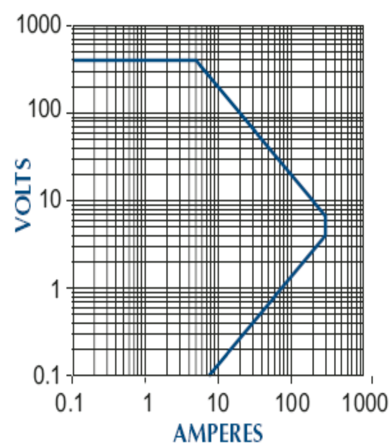


Impedance Measurements on Fuel Cells and Fuel Cell stacks at high currents: Autolab in combination with an electronic load. Part II

The use of impedance measurements on fuel cells under load, makes it possible to study the influence of the different fuel cell elements on the behaviour and (if present) the degradation of the fuel cell. However, most fuel cells operate at currents far higher than 1 A, while most potentiostat/FRA combinations are limited to 1 or 2 A. The maximum current of the PGSTAT302 with FRA2 module can be extended to 20 A by use of the Booster20A, but even 20 A is not enough to study a Polymer Fuel Cell of reasonable size (50 cm^2 for example). It is therefore desirable to be able to combine the PGSTAT302 with FRA2 module with an electronic load. The load is then capable of drawing the current from the fuel cell, whilst the Autolab is used to do the impedance measurements.

Choice of electronic load

For the experiments presented in this application note we have used the TDI Dynaload RBL 488 300-400-2000. The experiments described below also can be performed in combination with many other commercially available loads.



The main characteristics of this load are:

- Maximum current of 300 A
- Bandwidth of 20 kHz
- Measurement of voltages below 0.5 Volt possible with decrease in maximum current, as shown in the figure below.

Connections between Autolab and Load

The connections described below are specific for the TDI loads, where both the DC and AC signal need to be set externally; this can be done with the help of the Electronic Load interface. A complete description of the connections can be found in the installation note for the Electronic Load interface.
By using the connections described in the installation note, the current of the fuel cell is modulated by the frequency signal from the FRA2 module, the impedance is calculated based on that current and the measured potential response from the differential amplifier.

Experimental conditions

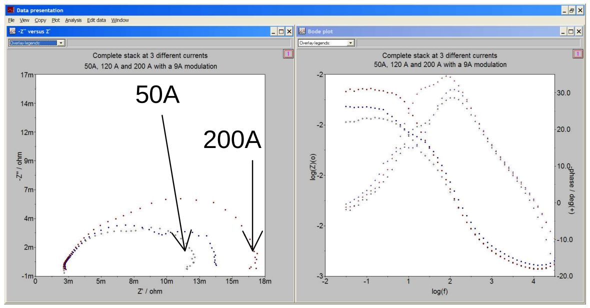
The load used in these experiments has a maximum current of 300 A , and a voltage range of 0-400 Volt.
Measurements were performed on a stack of five P(olymer)E(lectrolyte)M(membrane)F(uel)C(ell) fuel cells (200 cm^2) with Pt catalyst on both anode and cathode side. The fuel cell was operated on humidified H_2/O_2 or H_2/Air at 65 ºC. The fuel cell stack has been manufactured by NedStack fuel cell technology B.V., in Arnhem, The Netherlands.
For the impedance measurements an Autolab PGSTAT302 with FRA2 module was used, in combination with the FRA 4.9.006 software. The load was only used to sink the current. The voltage of the cell was measured by using the differential amplifier of the PGSTAT302.
The load was operated in Constant Current (CC) mode, whereas the PGSTAT302 was operated in potentiostatic mode. The current range in the FRA software was fixed to 1 A. Since the current input and the current output of the load both have a range of 300 A/10 V, some multiplication factors need to be set in order to obtain the correct impedance values. For the load input (300 A≡10 V) the DSG signal of the Autolab is multiplied by 30 (and an additional factor of 10 of the DSG, see the installation note), so that a 10 mV amplitude in the FRA software, results in a 3 A perturbation on the fuel cell. For the load output the signal (300 A≡10V)

needs to be divided by 30, in order to obtain a 1 A/V signal. These factors can be set in the dynload.ini file in the Autolab software.
In the software, in the FRA manual control window, the option 'use external inputs' needs to be selected.

Experimental Results

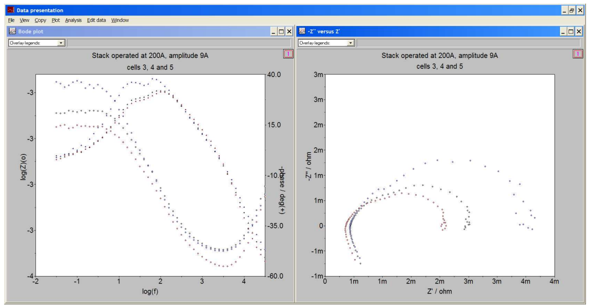
Impedance measurements were done at several DC currents with both air and O_2 and on the complete stacks as well as individual cells, with a frequency range from 10 kHz to 100 mHz, with different amplitudes.

The measurements shown below were done at 3 different DC currents; 50, 120 and 200 A while the fuel cell was operated on air. Both in the Nyquist and in the Bode plot, one can clearly see the increase in impedance at low frequencies with increase in DC current.



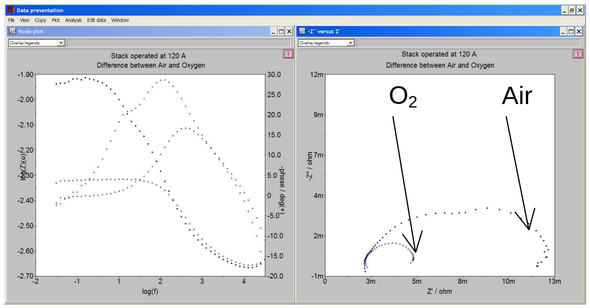
This increase in impedance can easily be explained by the fact that at low frequencies, a large contribution to the impedance comes from O_2 diffusion, an increase in diffusion is expected as the current goes up, since more O_2 (from air) is consumed.

Measurements on individual cells are shown below. The difference in impedance between the different cells is clearly visible. The stack was operated at 200 A, with a 9 A amplitude.



The difference between the individual cells in the graph above on the low frequency side is due to different diffusion properties and can be explained by for example different gas diffusion layers, or different gas flow patterns. On the high frequency side, one can also see slight differences, most probably due to the use of two different membranes.

The difference in operating a stack on air or oxygen can be seen in the next graphs. It is clear that the low frequency part of the curve is completely different when oxygen is used.



In the case of oxygen, there is hardly any influence of diffusion anymore on the cathode side, so the impedance at low frequencies will be much smaller.

The influence of using oxygen on the behavior of the individual cells is visible in the graph below. It is clearly seen that the diffusion effect, that was visible for air measurements, is now less pronounced. Only the difference at a high frequency, i.e. membrane conductance is still visible.