

Autolab Application Note FC05

Impedance Measurements on Fuel Cells and Fuel Cell Stacks at High Currents: Part 2 – Autolab in Combination with an Electronic Load

Keywords

Fuel cells; High current measurements; Electronic load; Electrochemical impedance spectroscopy

Summary

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 PGSTAT302N 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 cm² for example). It is therefore desirable to be able to combine the PGSTAT302N 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 488 400-300-2000. 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 contour plot in Figure 1

The contour plot shown in Figure 1 shows that the cell voltage must be at least 1.3 V in order to reach the full 300 A and that the maximum discharge current is 30 A when the voltage is 0.5 V. This means that this electronic load is particularly suitable for large fuel cell stacks.

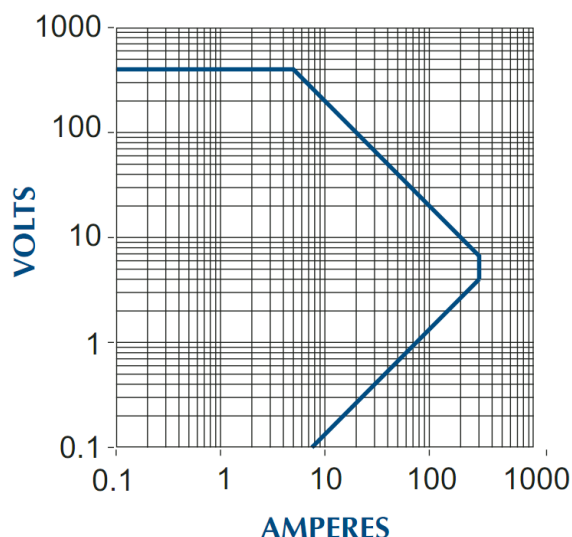


Figure 1 – Contour plot of the TDI Dynaload RBL488

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 400 Volt.

Measurements were performed on a stack of five PEMFC (200 cm²) with Pt catalyst on both anode and cathode side. The fuel cell was operated on humidified H₂/O₂ or H₂/Air at 65 °C. The fuel cell stack has been manufactured by

NedStack fuel cell technology B.V., in Arnhem, The Netherlands.

For the impedance measurements an Autolab PGSTAT302N with FRA2 module was used, in combination with the NOVA software. The load was only used to sink the current. The voltage of the cell was measured by using the differential amplifier of the PGSTAT302N.

The load was operated in Constant Current (CC) mode, whereas the PGSTAT302N was operated in potentiostatic mode. 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.

These values are defined in the software directly.

Experimental results

Impedance measurements were done at several DC currents with both air and O₂ and on the complete stacks as well as individual cells, with a frequency range from 10 kHz to 100 mHz, with different amplitudes.

Figure 2 shows a typical Nyquist plot obtained at a discharge current of 120 A and 200 A while the fuel cell was operated on air. 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 O₂ diffusion, an increase in diffusion is expected as the current goes up, since more O₂ (from air) is consumed.

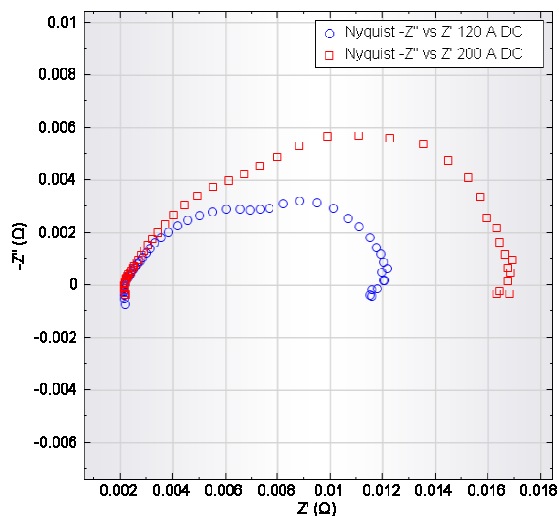


Figure 2 – Typical Nyquist plot obtained at a discharge current of 120 A (red squares) and 200 A (blue circles)

Measurements on individual cells are shown in Figure 3. The difference in impedance between the different cells is clearly visible. The whole stack was operated at 200 A, with a 9 A amplitude and the impedance measurement was performed on individual cells in the stack.

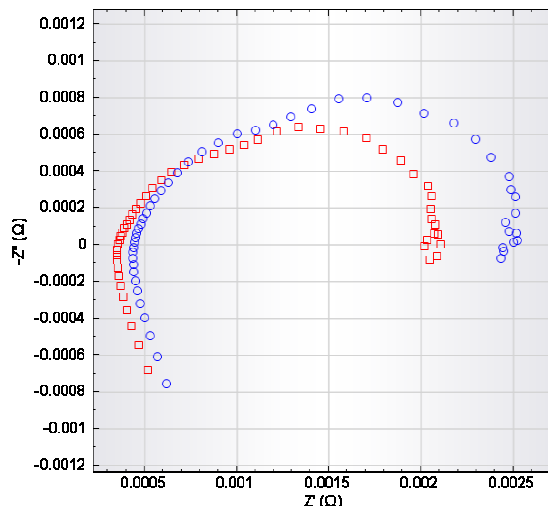


Figure 3 – Nyquist plots corresponding to individual cells in the stack, while the stack is operated at 200 A

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.

Figure 4 shows the difference between in operating a stack on air or oxygen. It is clear that the low frequency part of the curve is completely different when oxygen is used.

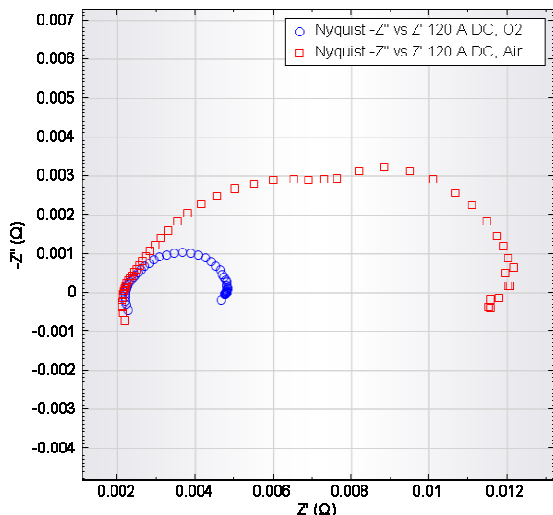


Figure 4 – Nyquist plots obtained at 120 DC discharge current with the stack operated with pure O₂ (blue circles) and with air (red squares)

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 can be observed in Figure 5, especially when compared with Figure 3.

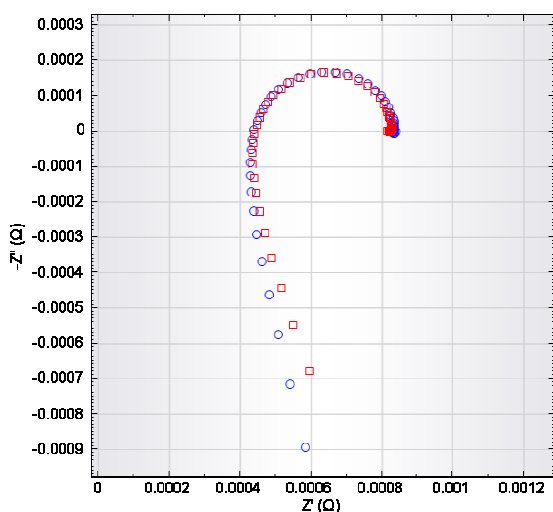


Figure 5 – Nyquist plots corresponding to individual cells in the stack, while the stack is operated at 120 A DC, on pure oxygen

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.

Date

1 July 2011