Application Area: Fuel Cells

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

Keywords

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

Summary

Electrochemical impedance spectroscopy (EIS) is a powerful technique to study different fuel cell elements and their influence on the overall performance of fuel cell. EIS also gives valuable information on degradation mechanism of a fuel cell over its life time. Most of the fuel cells operate at high currents, while the maximum current of most of PGSTATs are limited to few amps. The maximum current of the Autolab PGSTAT302N can be extended to 20 A by using an Autolab Booster20A. However, even 20 A might not be enough to study a Polymer Fuel Cell of reasonable size (50 cm^2 for example) as they might deliver currents higher than 20 A. Therefore, to perform EIS on fuel cells, a combination of PGSTAT and electronic load (e-load), is desirable. The electronic load is then capable of drawing the high currents from the fuel cell, and the Autolab PGSTAT performs the impedance measurements.

Choice of electronic load

For all the experiments in this application note, a TDI Dynaload RBL 488 400-300-2000 was used. The experiments can also be performed in combination with other commercially available e-loads.

The main characteristics of this e-load are:

- Maximum current of 300 A
- Bandwidth of 20 kHz
- Measurement of voltages below 3 V possible with decrease in maximum current, as shown in the contour plot in Figure 1.

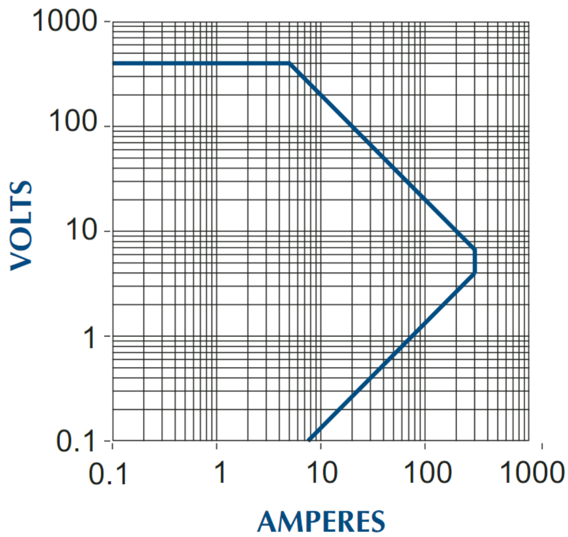

Figure 1 – Contour plot of the TDI Dynaload RBL488.

Here, it can be noticed that the cell voltage must be at least 3 V in order to reach 300 A, and that the maximum discharge current is 30 A when the voltage is 0.4 V. This means that this electronic load is particularly suitable for large fuel cell stacks.

Connections between Autolab and Load

The connections between the PGSTAT302N and TDI electronic load, are done with the help of the Dynamic Load (Dynload) interface Figure 2.

Figure 2 - The Dynamic Load Interface.

The current of the fuel cell is modulated by the frequency signal from the FRA32M module and the impedance is calculated based on the same current and the measured potential response from the differential amplifier.

Experimental conditions

The electronic load used in these experiments has a maximum current of 300 A, and a voltage range of 400 V.

The measurements were performed on a stack of five proton-exchange membrane fuel cells (PEMFCs, area 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 °C. The fuel cell stack has been manufactured by NedStack fuel cell technology B.V.

For the impedance measurements, a Metrohm Autolab PGSTAT302N equipped with a FRA32M module was used, in combination with the NOVA software. The load was only used to draw current from the fuel cell. 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.

Experimental results

The impedance measurements were done at several DC currents under operation of both air and oxygen. The EIS was done on both fuel cell stack and individual cells, with a frequency range of 10 kHz to 100 mHz. Different amplitudes were applied at different experiments.

Figure 3 shows a typical Nyquist plot obtained from the EIS experiment performed on the fuel cell, at a discharge current of 120 A (blue dots) and 200 A (red squares), while the fuel cell was operated in air.

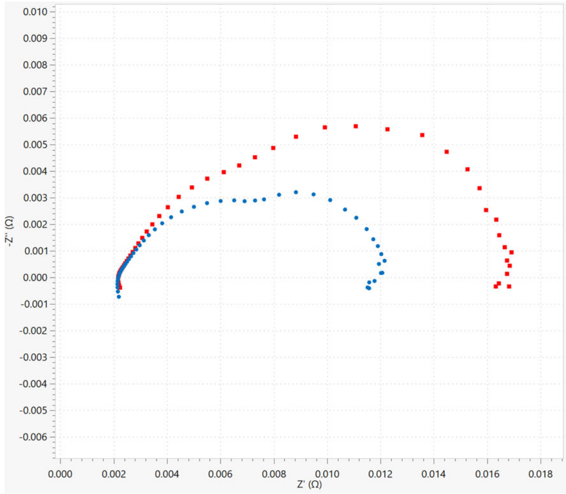

Figure 3 – Typical Nyquist plot obtained at a discharge current of 120 A (blue dots) and 200 A (red squares) while being operated under air.

Figure 3 clearly shows that the impedance at lower frequencies increases with discharge current. This increase in impedance is most likely due to the fact that at low frequencies, a large contribution to the impedance comes from oxygen diffusion. Since more oxygen (from air) is needed at higher currents to be consumed in fuel cell, an increase in diffusion impedance is expected when operating fuel cell at higher currents.

Measurements on individual cells within a fuel cell stack are shown in Figure 4.

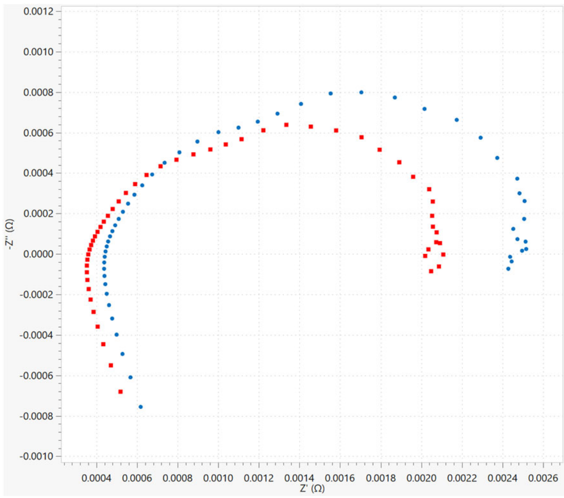

Figure 4 – Nyquist plots corresponding to individual cells in the stack, while the stack is operated at 200 A in air.

Figure 4 shows the Nyquist plot obtained from two different cells. The whole stack was operated at 200 A, and an amplitude of 9 A was applied on the individual cells in the stack in order to perform the EIS experiment. It is clear that these two cells have different impedances and does not behave identically in terms of the internal resistance.

The difference between the individual cells at lower frequencies is most likely due to the different diffusion properties. This can be explained by different gas diffusion layers, or different gas flow patterns. At higher frequencies, slight differences are also present, most probably due to the use of two different membranes.

Figure 5 shows the difference between in operating a stack on air or oxygen.

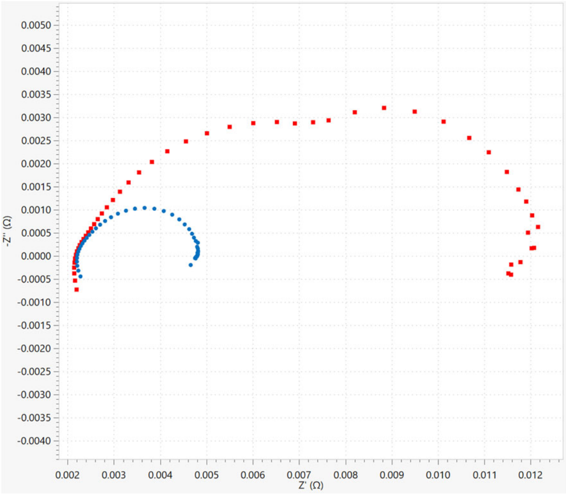

Figure 5 – Nyquist plots obtained at 120 DC discharge current with the stack operated with pure oxygen (blue circles) and with air (red squares).

From Figure 5, it is clear that the cell operated in the air has a much bigger impedance at lower frequencies. This again could be due to the diffusion impedance of the oxygen in the air. When operating in pure oxygen, there is hardly any influence of diffusion on the cathode side, so the impedance at low frequencies is much smaller than the case of fuel cell operation in air.

Figure 6 shows the Nyquist plot obtained from individual cells within a stack under operation of pure oxygen.

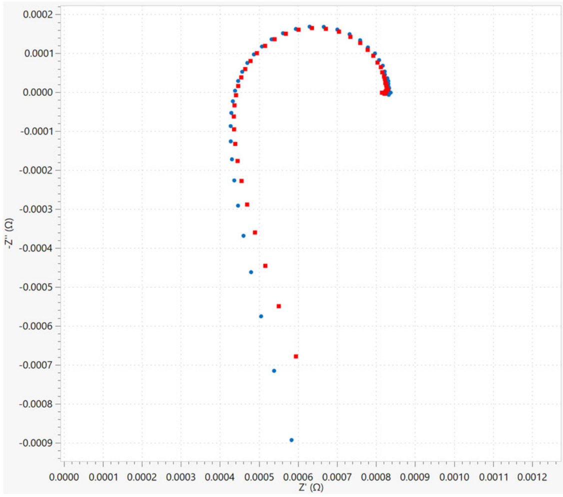

Figure 6 – Nyquist plots corresponding to individual cells in the stack, while the stack is operated at 120 A DC, on pure oxygen.

It is clear that hardly any differences can be seen in both plots. This shows that when operating the fuel cell in pure oxygen the individual cells show identical impedances where as in the case of air, individual cells behave very differently, specifically at lower frequencies (see Figure 4).

At higher frequencies, however, there is slight difference in the impedance of the individual cells which could be due to the differences in the membrane conductance.

Date

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For more information

Additional information about this application note and the associated NOVA software procedure is available from your local **Metrohm distributor**. Additional instrument specification information can be found at **www.metrohm.com/en/products/electrochemistry**.