DELYCIOUS

Clean Hydrogen Partnership

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# Lab-scale EIS Test Report


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# About DELYCIOUS

As Europe accelerates its transition to clean energy, the Net Zero Industry Act identifies low-carbon hydrogen production as a strategic priority. DELYCIOUS tackles key challenges in water electrolysis technology, focusing on extending electrolyser lifespans and reducing operational costs under variable renewable energy sources. In DELYCIOUS, the development of cost-efficient, innovative, open, universal, and safe diagnostic tools to investigate the chemical and electrochemical properties of electrolysis systems is foreseen. This project combines Raman Spectroscopy (Raman) and Electrochemical Impedance Spectroscopy (EIS), to explore the chemical and electrochemical properties of electrolysis systems. By using both physical and data-driven modeling, it will be possible to identify important degradation parameters. To ensure that the diagnostic tools work effectively in various temperature ranges and across various electrolysis technologies, three technologies namely Alkaline Electrolysis (AEL), Proton Exchange Membrane Electrolysis (PEMEL), and Solid Oxide Electrolysis (SOEL) are addressed in this project, with a demonstration on alkaline electrolysers beyond 100 KW.

## Consortium

Fraunhofer IWES

Coordinator

Air Liquide

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DUMAREY

HORIBA

etaflorence

stargate hydrogen

SIVONIC



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# Purpose and Application

The Electrochemical Impedance Spectroscopy (EIS) is a highly precise measurement technique to measure the AC resistance (impedance) of various materials and components. It is widely applicable in multiple fields, including electronics, material science, and biomedical research. Impedance measurements provide valuable insights into the electrical properties of components, circuits, and biological tissues, making the device an essential tool for researchers and engineers alike.

With this Deliverable, SIVONIC provides a test report ensuring and demonstrating that the EIS device can provide the measurement capabilities within the scope, is essential for the developments to follow.
This report summarizes the calibration capability and shows an example measurement of an AEL cell.



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# 1. Device Calibration

## 1.1. Introduction and Calibration Process

Accurate measurement of electrical impedance is essential for the upcoming investigations. However, the reliability of the measured data critically depends on the accuracy and stability of the measurement system. Even minor deviations in measurement characteristics, caused by factors such as temperature drift or aging of electronic components, can lead to significant measurement errors.

For this reason, regular calibration is indispensable. Calibration ensures that the measuring device delivers results traceable to standardized reference values and helps to identify and compensate for systematic sources of error.

The EIS device used here is equipped with multiple measurement ranges to cover a wide impedance spectrum, as typically encountered in electrolyzers: from just a few microohms up to several ohms. Each range is specifically optimized to ensure maximum measurement accuracy under varying operating conditions.

In the present case, the impedance of the device under test (DUT), an exemplary electrolyzer cell in the Lab-scale environment, falls squarely within the upper measurement range of the EIS system. This range is intended for medium to higher impedances and provides stable and sufficiently accurate measurements over a broad frequency spectrum. The lower measurement range, by contrast, is specifically designed for extremely low impedances, from a few milliohms down to the microohm scale, and offers significantly higher resolution and measurement precision in that domain. Typical DUTs for this measurement range are cells with large active areas and correspondingly very low impedances

To confirm the measurement capability, the instrument is calibrated across the relevant impedance range. This procedure demonstrates the accuracy and reliability of the impedance measurement system.

## 1.2. Calibration Results

After completing the calibration, a low-resistance power shunt with a nominal resistance of 201.17 mΩ was measured. The subsequent measurement showed an extremely small deviation from the target value which falls under the uncertainty of the measurement. The measured value closely matched theoretical expectations as well as previously validated reference data, confirming the device's capability to resolve low-ohmic resistance values with high precision. Given that the deviations are so minor, it can be safely assumed that, when measuring a real electrolyzer cell, only negligible residual measurement errors will remain.

The following figures illustrate the frequency-dependent behavior of both the magnitude and phase of the impedance. These plots are provided separately for the system channel and for each of the installed cell measurement channels. This representation allows for a direct comparison of the individual channel responses and highlights any deviations or characteristic features in the impedance spectra across the different measurement paths.



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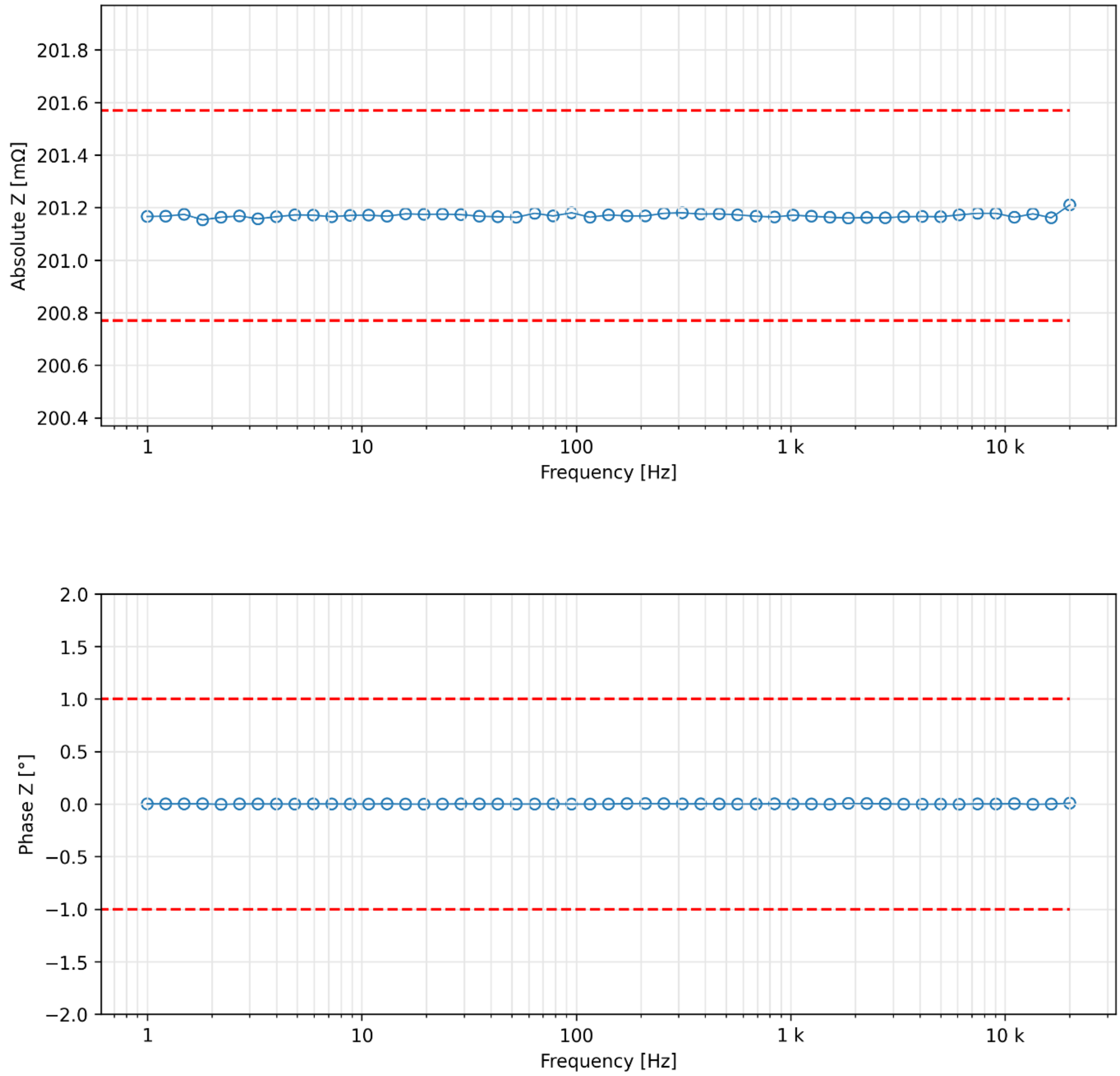


*Figure 1: Measurement Results after Calibration for the System Channel*



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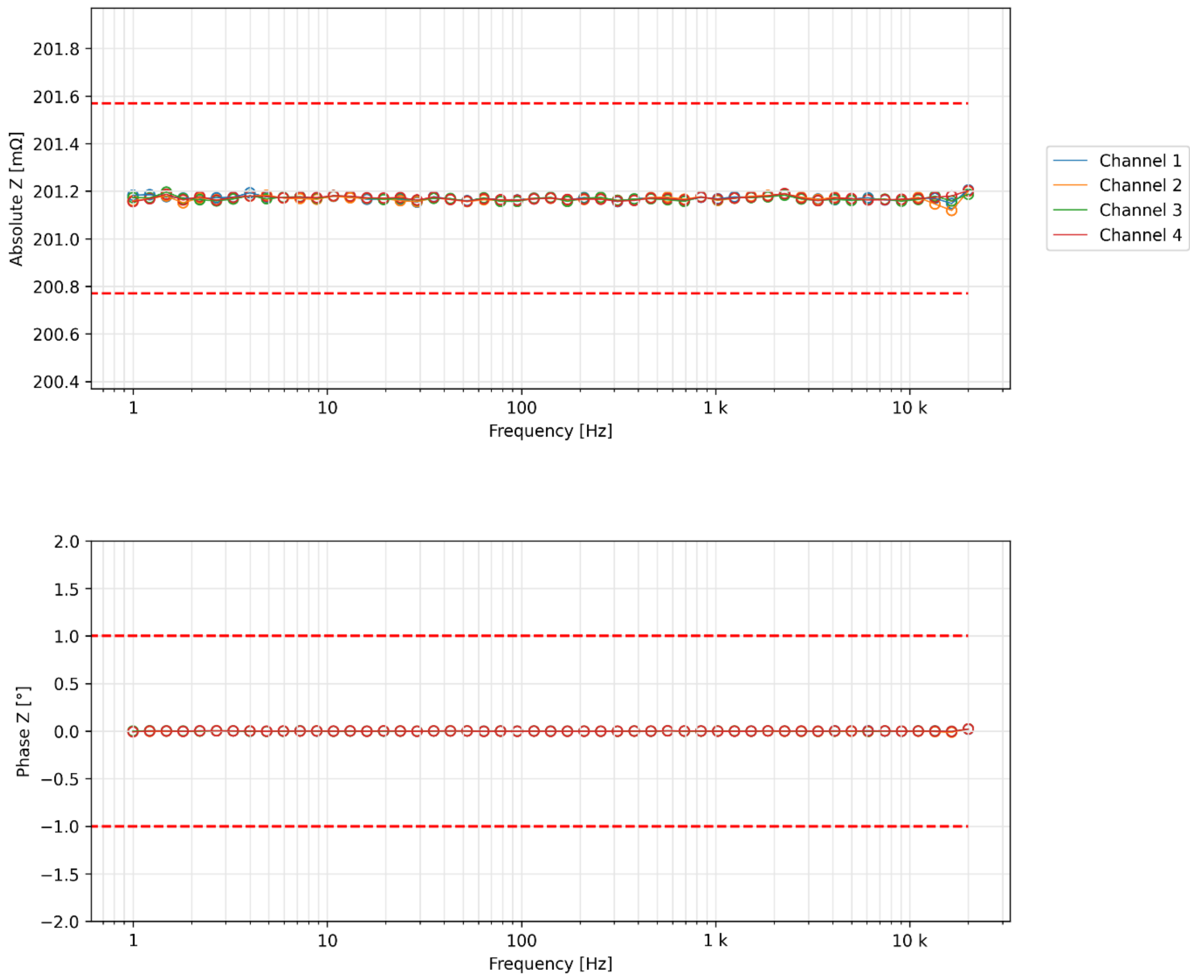


*Figure 2Measurement Results after Calibration for Cell Channel 1 - 4*

# 2. Measurement Result

The following shows the result of an electrochemical impedance spectroscopy measurement performed on a real electrolysis cell. The Nyquist plot is exceptionally clean and of high quality. There is no evidence of noise, capacitive coupling, or inductive artifacts. The data points form a smooth and continuous curve, which allows for unambiguous interpretation and precise modeling. The transitions between the high-frequency and low-frequency regions are clearly resolved, indicating that the measurement was carried out under stable and well-controlled conditions.



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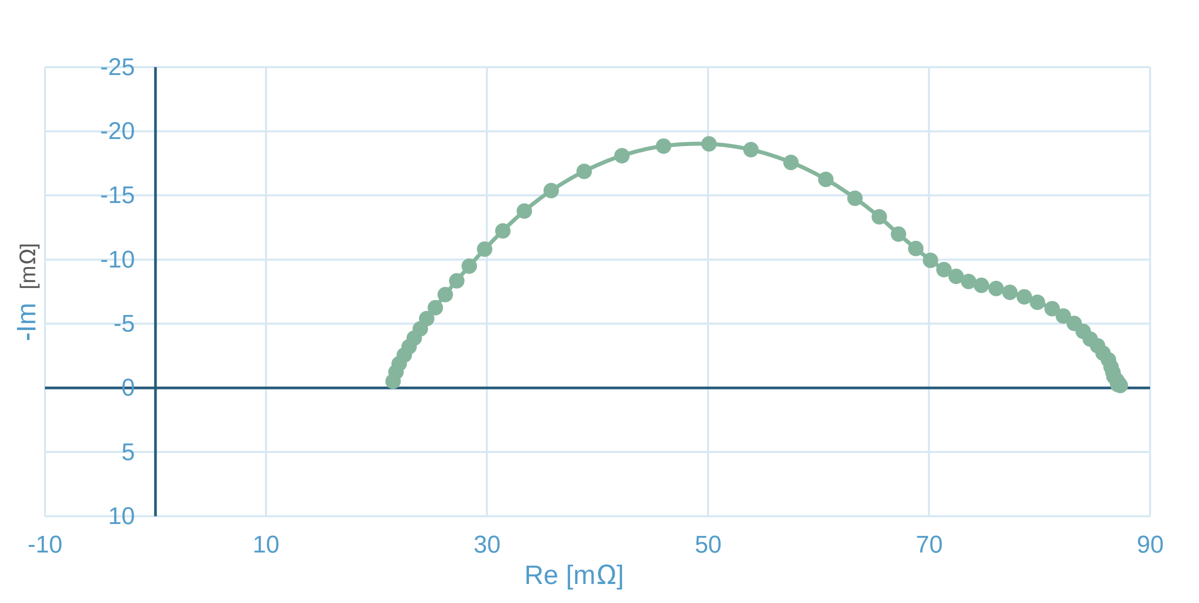


*Figure 3: Nyquist plot from the EIS measurement of an example electrolysis cell*

At high frequencies, the point where the curve meets the real axis at low impedance corresponds to the ohmic resistance of the system. This value reflects the ionic conductivity of the electrolyte, as well as contact and interfacial resistances within the cell hardware.

Following the high-frequency region, the plot exhibits a well-formed semicircle that represents the charge transfer process and double-layer capacitance at the cathode interface. The symmetry and smooth curvature of this semicircle suggest a kinetically well-behaved reaction with a homogeneous electrode surface. There are no signs of dispersion or distortion, indicating that the cathodic reaction proceeds uniformly across the electrode area.

At lower frequencies, a second semicircle appears, distinct and well separated from the first. This part of the spectrum is typically associated with the oxygen evolution reaction at the anode, which tends to be more complex and involves slower kinetics. The fact that this second semicircle is clearly resolved and not merged with the first is a strong indication of well-separated time constants in the system. It also implies that there is minimal interference between the processes at the two electrodes, which speaks for the quality of the cell design and measurement setup.

The Nyquist plot from the EIS measurement shows a high-quality and reliable dataset. The curve is smooth and continuous, with no visible artifacts or irregularities. All relevant frequency regions are clearly resolved, enabling straightforward interpretation and modeling. The result confirms that the measurement system is functioning with high accuracy and resolution across the full frequency range.



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