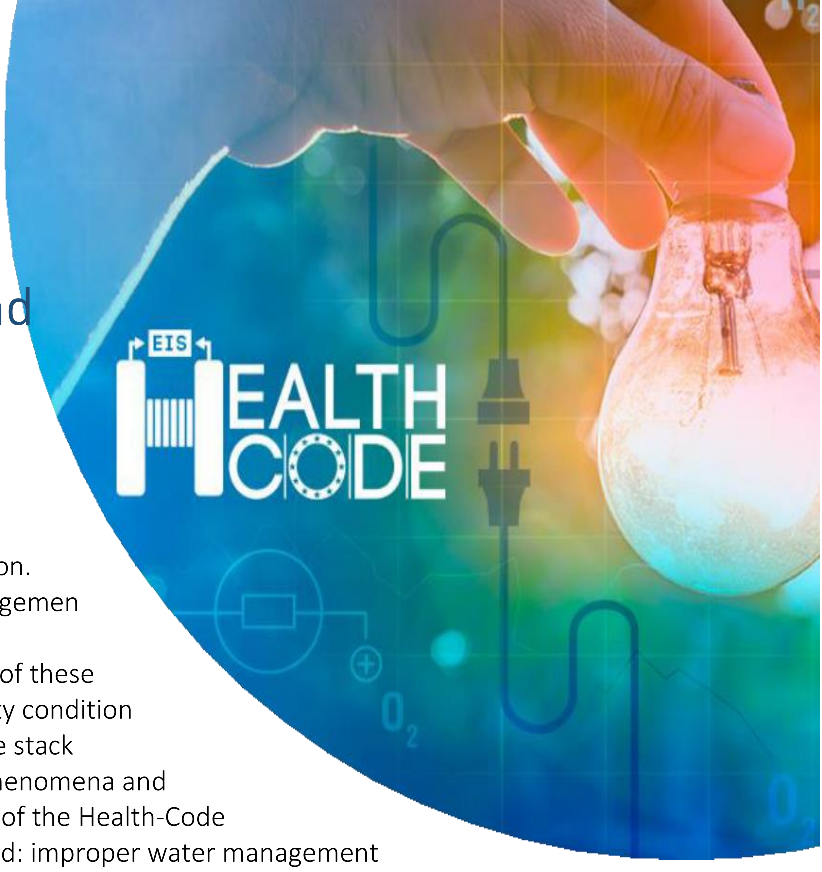
Public Abstract

Deliverable D4.2 Relevant features extractionfor diagnosis and lifetime extrapolation



In the framework of the “0 emission” policies, Proton exchange membrane fuel cell (PEMFC) appears as a suited eco-friendly alternative to face the continuous increase of energy consumption. Nevertheless, long operations and improper managemen conditions can induce the PEMFC performance and durability reduction. When one of these circumstances or their combination occurs, a faulty condition is caused. Faulty conditions can severely affect the stack performance, introducing several degradation’s phenomena and then accelerating the FC ageing. In the framework of the Health-Code project, the following faulty conditions are analysed: improper water management (drying and flooding conditions), reactants’ starvation (fuel and oxidant) and poisoning phenomena (CO and H2S).

This deliverable deals with the analysis of the stack measurements, such as the voltage output and the electrochemical impedance spectroscopy (EIS), oriented to develop FC on-field monitoring and diagnosis approaches. To this purpose both stack operations at nominal and faulty conditions are investigated. As a consequence stack measurements are considered as generic tools to identify on-field the stack state of health (SoH). Particularly features selection is performed combining the data obtained by the experimental activity of T2.2 and those resulting from T4.1. This extraction is represented by the selection of specific frequencies (which could differ, depending on fault nature and/or amplitude) in stack voltage signal or in EIS spectra measurements). Particularly in section two, the different features are presented and classified depending on the considered diagnostic approach. Three major diagnostic approaches are introduced: model-based (implemented by UNISA - P01), data-driven (implemented by UFC - P07) and signal-based (implemented by EIFER - P04).

The diagnostic algorithm developed by UNISA is based on features derived from an Equivalent Circuit Modelling (ECM) approach. This methodology uses specific circuital elements to represent the impedance characteristic of the single cell/stack at different operating conditions. The EIS measurements are used as reference experimental data from which these features are extracted. Then, their value is collected and associated to all the investigated operating conditions (i.e., both nominal and faulty). The ECM elements thus represent the features that are used within the ECM-based diagnostic algorithm for faults detection and isolation (fig.1).

Concerning data-driven approaches, developed by UFC, fuzzy clustering method is commonly used for pattern recognition. To this purpose, clusters are associated to the different faults, while data are represented by relevant features. A double-fuzzy method, combining the unsupervised classification capability of the fuzzy c-means clustering with the decision-making ability of the fuzzy-logic approaches has been developed. In this case, the features selection is a mandatory step that combine both experimental data analysis and expertise knowledge. To select the most valuable features, features are firstly evaluated from the EIS spectra data-set. During this step all the operating conditions, nominal and faults are considered. Subsequently, the different features are normalized and the related variance values are evaluated. The normalized features with the major variance values are considered as the major candidates for the features’ space construction. In parallel, the correlative coefficients among all the features are calculated to verify the redundancy contained into the different features. Subsequently the most valuable features are selected and the feature space constructed. During this step, the fuzzy c-means (FCM) technique is performed to obtain different clusters (fig.2).

Signal-based approach, developed by EIFER, refers on compensation of the measured EIS spectra by former measured nominal EIS spectra. Several EIS spectra are measured in nominal conditions, afterwards the mean value and the standard deviation are calculated. The averaged EIS spectra is subtracted from any

measured spectra. If the result of the compensation is within the single or double standard deviation of the mean EIS spectra, the measured spectra is considered as another nominal condition, an advantage of the method is that the database can forget old nominal conditions and slowly evolve due to ageing effects. In this case, any faulty condition is always compensated with the most recent nominal condition of the stack. If the result is higher than the double standard deviation, the extracted features are considered for the diagnosis of the stack. The presented Bode plots can be read like the fault effect on the nominal condition. The extracted features are the frequencies with values above the double standard deviation (fig.3)

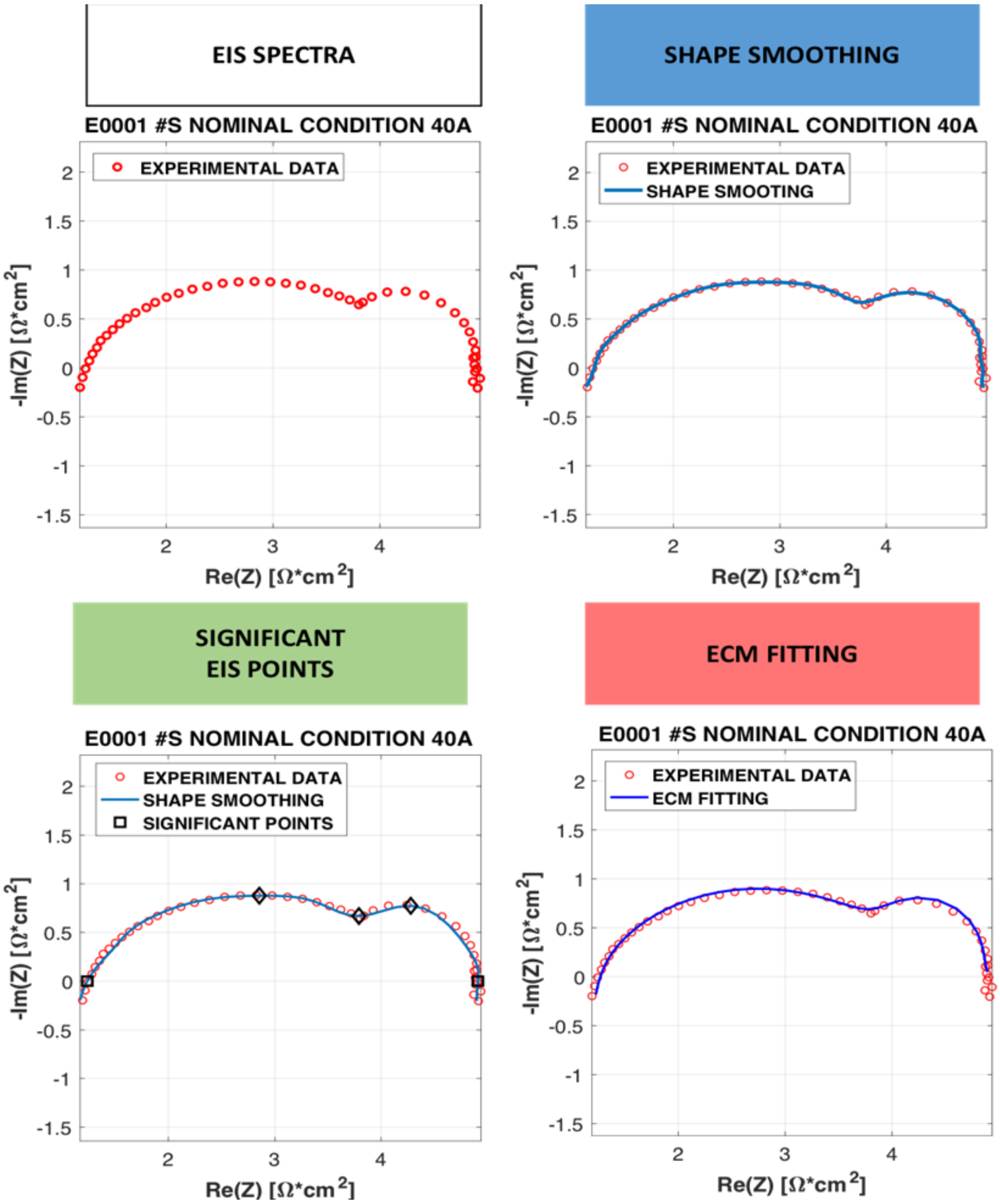


Fig.1: Top: Equivalent Circuit Model (ECM) generic structure; Bottom: Parameters identification procedure: the measured EIS spectrum is loaded (top-left) and filtered (top-right); the significant points are extracted (bottom-left) for spectrum fitting and parameter identification (bottom-right).

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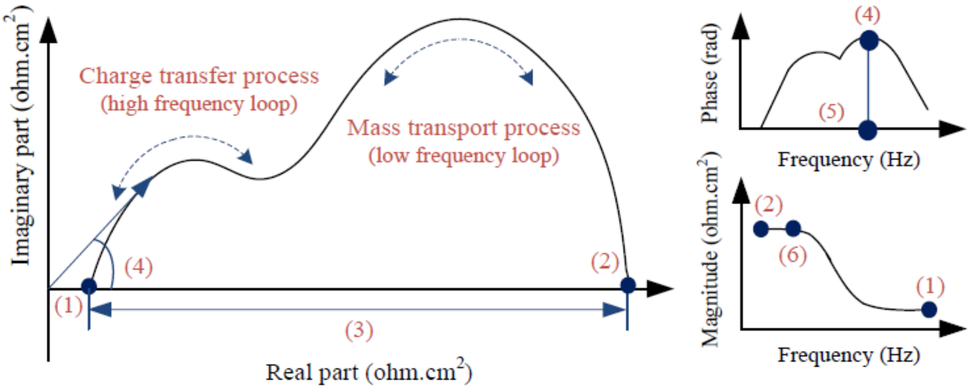
Title of figures:

Figure 1: XXX

Figure 2: XXX



Fuzzy c-means clustering results

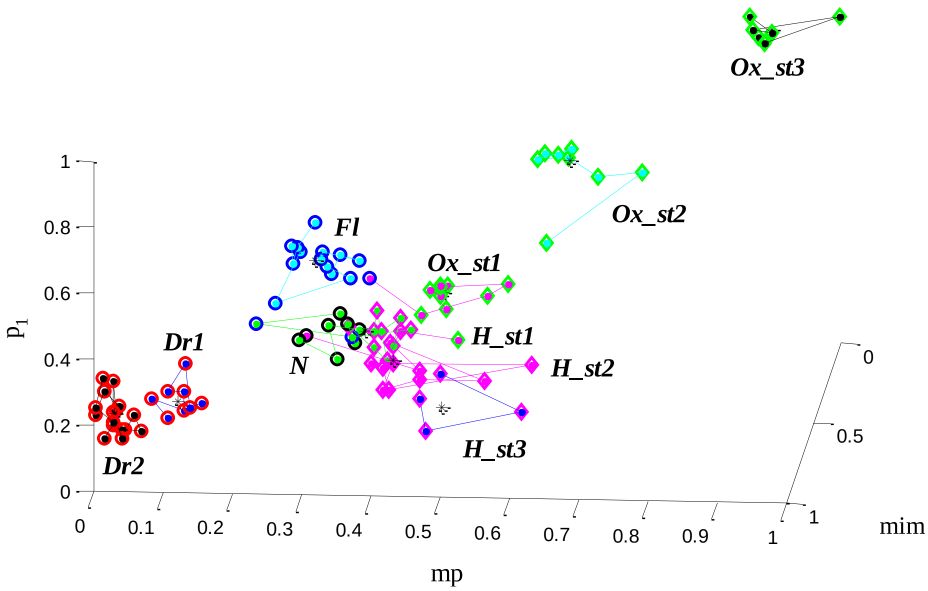


Fig.2: Top: Feature representation; Bottom: Fuzzy C-means results at 120 A: 3D representation

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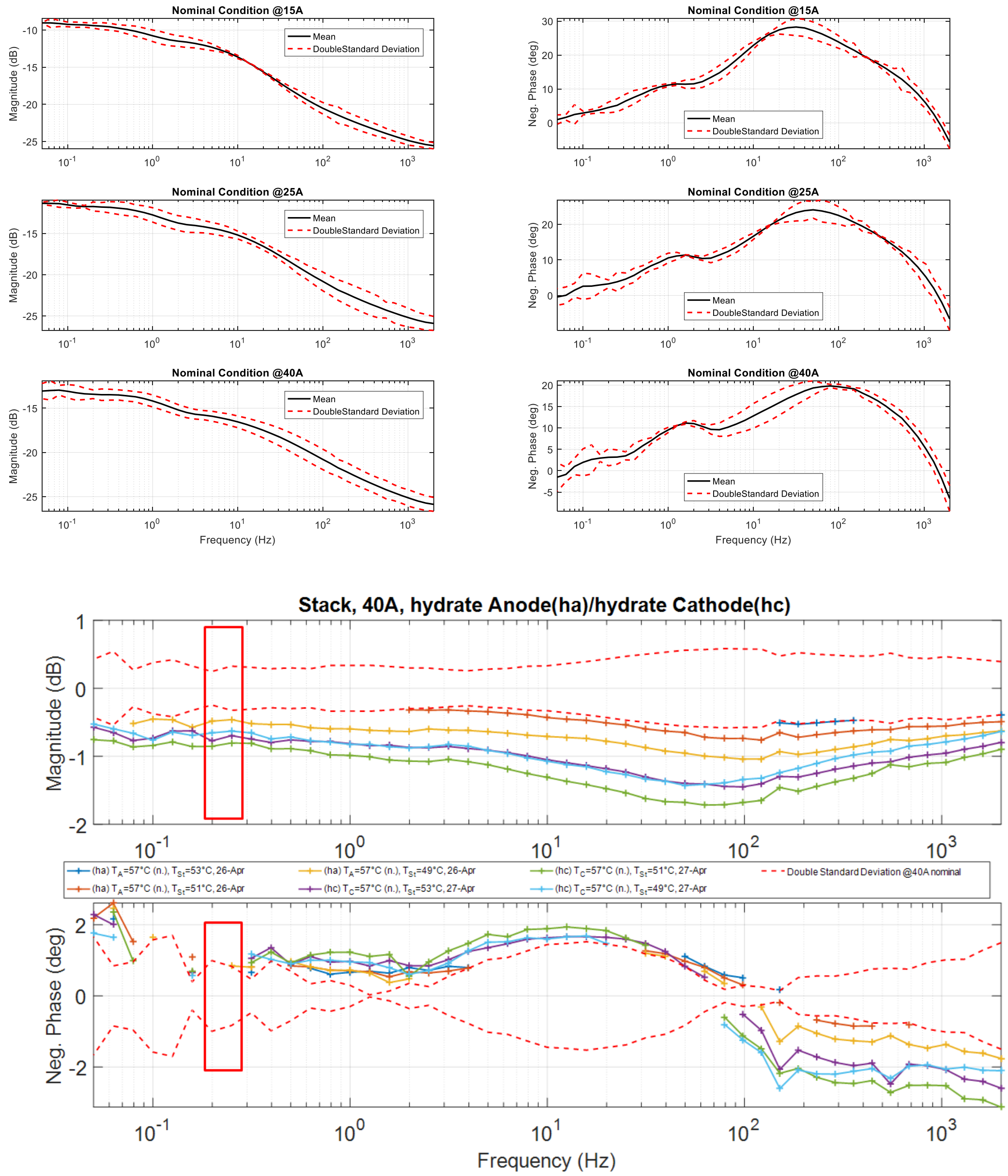

Fig.3: Top: double standard deviation for Bode plot: Bottom: Anode and Cathode hydration for all intensity levels at 40A. The red frames in negative phase and the magnitude mark the frequencies, which were used as identification for flooding/hydration