Modelling and identification of the dominant phenomena in hydrogen fuel-cells by the application of DRT Analysis

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Abstract

This paper proposes the use of the distribution of relaxation times (DRT) for the analysis of the dynamic behavior of hydrogen fuel-cells. With this aim it presents a new method to compute the DRT directly from electrochemical impedance spectroscopy (EIS) data.

The method is formulated as a nonconvex complex domain optimization problem where each EIS spectra is approximated by a general fractional-order Legendre basis. The DRT is computed directly from the Legendre basis functions and validated against the experimental data. The method is tested with real EIS data collected from an hydrogen polymer electrolyte fuel-cell under different operating conditions and the results are discussed.

Keywords: Hydrogen fuel-cells, impedance spectroscopy, distribution of relaxation times, nonconvex optimization

1. Introduction

The urge for efficient and environmental friendly technologies addressing energy generation systems has been a major driving force for the research in fuel cells. In particular, hydrogen polymer electrolyte fuel cells (PEMFC) are a strong alternative for developing portable applications since they can achieve high-energy densities. Their performance depends on multiple factors where, with the uppermost importance for the development of highly reliable fuel cells, stand the mass transport phenomena inside the cell and the catalyst reaction kinetics, together with their coupling effects.

Electrochemical impedance spectroscopy (EIS) is an analysis technique that is commonly used as a base diagnostic technique because it retrieves information about the frequency response characteristics of the electrochemical system, but its direct use is limited. The usual approach to address EIS data is based on the development of models to represent the electrochemical phenomena. The modeling step is based on the use of equivalent electric circuits as a mathematical representation of the process in the Laplace domain.

Although this approach is widely used in the analysis of EIS data, it needs an informed insight on the nature of the phenomena inside the electrochemical cells. An alternative can be devised by using the distribution of relaxation times, which can be directly linked with the impedance spectrum through the Hilbert transform. Determining the distribution of relaxation times using impedance data requires the solution of a Fredholm integral equation of the first kind, which is known as an ill-posed inverse

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