Sensitivity Analysis for High Temperature Proton Exchange Membrane Fuel Cell

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Abstract

A Proton Exchange Membrane Fuel Cell (PEMFC) is an electrochemical device, which converts a part of heat from the formation of water into electricity. Each cell has a Membrane-Electrode Assembly (MEA) which is placed between two electrically conducting plates having gas flow channels. An MEA is made of a solid proton-conducting electrolyte sandwiched between two electrodes (anode and cathode). Each electrode is composed of a porous Gas Diffusion Layer (GDL) backing a microporous catalyst layer which is placed adjacent to the electrolyte. The solid electrolyte is impervious to gases. The various attributes of MEA's components influence the final performance of the cell. It is therefore useful to know how sensitive the fuel cell performance is to each of these attributes. In this paper, we present parametric sensitivity analysis of high temperature PEMFC performance. We define PEMFC performance as the average current density obtained at a fixed operating voltage (~ 0.6 V). Additional characteristics of the PEMFC such as High Frequency Resistance (HFR) and Charge Transfer Resistance (CTR) obtained using Electrochemical Impedance Spectroscopy (EIS) are also used as measures of the performance of PEMFC.
The HT-PEMFC was modeled using the COMSOL Multiphysics® Batteries & Fuel Cells module, which consists of symmetrical distribution of gas flow channel, gas diffusion layer and catalyst layer about a central proton exchange membrane. Parameters resulting from physically determinable properties of each component of the MEA were identified and assigned experimentally veritable values based on literature and by comparison with experimentally determined polarization data. Simulations were also performed by adding a frequency perturbation to the applied voltage, thereby predicting EIS curves. The polarization and EIS simulations were performed for different values of parameters. Sensitivity analysis was obtained by plotting the change in PEMFC performance versus change in parameters varied one at a time. Results show that cell performance and CTR are most sensitive to the cathodic Tafel slope, whereas HFR is most sensitive to membrane properties. While these might be obvious results, several additional subtleties in parametric sensitivity were observed, which will be discussed in the paper.