Nonlinear Behaviour of PEM Fuel Cells operated in auto-humidification mode

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Abstract

The proton conductivity of Proton Exchange Membrane (PEM) fuel cells is mainly influenced by the water content of the polymer electrolyte membrane. It changes nonlinearly by nearly one order of magnitude for typical fuel cell operation conditions. As water is produced in the cathodic reaction, this fuel cell type may exhibit autocatalytic behaviour: an increased membrane water content results in an increased proton conductivity which elevates the electrode reactions and therewith the water production. This effect can be a source for steady-state multiplicities especially when the cell is connected to a constant load resistance as firstly reported by Moxley *et al.* in 2003.

This contribution focuses on a systematic model based investigation of the solution behaviour of PEM fuel cell models with special regard to steady state multiplicities, caused by water content dependent membrane conductivity.

With the help of a 1D "through the membrane" model family, starting from a simple one-state base model it was possible to derive analytical criteria for the occurrence of steady state multiplicities. A numerical analysis of the stepwise-refined models by bifurcation analysis was subsequently done in order to investigate the refinement's influence on the solution behaviour.

The base model, which can be solved analytically, shows regions of three to zero solutions especially for low reactant flows and low inlet humidities (typical conditions for auto-humidification mode). For a certain load resistance a certain maximum inlet flow rate exists below which multiplicities can occur. Between a minimal and a maximal inlet humidity up to two stable and one instable steady state solutions were found to coexist. Additionally for a certain load resistance and a certain inlet flow rate a critical inlet humidity can be calculated above which flooding might occur.

Keywords: PEM Fuel Cell, Nonlinear Dynamics, Steady State Multiplicity, Bifurcation Analysis