2D Transient Modeling of Hydrogen Purge and Temperature Effects on the Performance of PEM Fuel Cells

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To develop proper hydrogen purge strategies in combination with temperature and water management, CFD modeling is an important tool. Dynamic simulation of water and temperature distribution during and between purges, which is linked to the cell performance, facilitates the development and test of different control strategies. The goal of an effective purge strategy would be to increase the interval between purges by changing operation conditions such as fuel cell temperature or flow rates and thus minimizing the loss of hydrogen. The present dynamic 2D CFD model is an extension of the work of Strahl et al. [1]. The extended model takes into account experimentally validated reaction kinetics described by a modified Butler-Volmer approach as well as two-phase flow of water and nitrogen crossover. The model was experimentally validated with the fuel cell stack under study and compared to the published experimental data by Husar et al. [2] and Strahl et al. [3]. Experimental observations of Strahl et al. [3] revealed that flooding on the anode and drying of the cathode catalyst layer may occur simultaneously during purged operation. The presented CFD model is capable of simulating dynamic two-phase water transport along the channel and across the membrane-electrode-assembly in relation with fuel cell performance. Hydrogen starvation on the anode caused by liquid water and nitrogen accumulation in the anode channel and gas diffusion layers is discussed. Liquid water transport dynamics in combination with temperature dependent evaporation dynamics are compared using liquid water saturation distribution and voltage transients during temperature changes. The simulation results explain the experimental observations in [3] and provide the necessary understanding for the development of efficient hydrogen purge control strategies. Especially, the relation between fuel cell performance, liquid water accumulation on the anode and simultaneous cathode catalyst layer drying during purged operation is investigated.

[1] S. Strahl, A. Husar and M. Serra. (2011). Development and experimental validation of a dynamic thermal and water distribution model of an open cathode proton exchange membrane fuel cell. Journal of Power Sources, 196(9), 4251–4263.
[2] A. Husar, S. Strahl and J. Riera. (2012). Experimental characterization methodology for the identification of voltage losses of PEMFC: Applied to an open cathode stack. International Journal of Hydrogen Energy, 37(8), 7309-7315.
[3] S. Strahl, A. Husar and J. Riera, (2014). Experimental study of hydrogen purge effects on performance and efficiency of an open-cathode Proton Exchange Membrane fuel cell system. Journal of Power Sources, 248, 474-482.