Performance and efficiency optimization of PEMFC stacks during operation

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The operating conditions essentially determine the performance and the efficiency of a polymer electrolyte membrane fuel cell (PEMFC) stack in a fuel cell system. Due to space and weight limitations in such systems, the optimization of the stack performance and efficiency is mandatory to assure high power output and fuel utilization. Typically, the operating conditions are defined in a system by look-up tables and are not adapted over stack lifetime. But the best operating conditions can vary over the lifetime of a PEMFC stack due to the presence of different degradation phenomena, e.g. resulting in changes of the electrode structure, the electrode hydrophobicity, and the catalyst activity. Predefined look-up tables cannot cover this behavior and the use of an optimization algorithm is highly favorable to facilitate optimal stack operation over the entire lifetime.

In the presented work, a new stack efficiency η^*_{stack} is defined to represent the stack efficiency in a system because the commonly used stack electrical- and fuel efficiencies do not take into account the operating conditions of the examined stack [1]. This efficiency covers all power losses directly connected with the applied conditions including theoretical losses for stack feed stream conditioning, like pressurization and air pumping. Examples will be given which power losses are relevant and dominant for different applications.

The performance determining conditions are characterized by the stack temperature as well as the stoichiometric values, the relative humidity, and the pressures of the reactants. Their effect on the stack performance is non-linear and synergistic. A separate optimization of the parameters one after another is not meaningful. Therefore, a direct-search algorithm, the Nelder-Mead simplex, was used for the simultaneous optimization of all parameters [2]. The optimization process will be explained in detail and presented results will demonstrate that the efficiency can be improved in a running PEMFC stack by up to 4 % only by optimizing the operating conditions.

Literature:

[1] P. Piela, J. Mitzel, Polymer electrolyte membrane fuel cell efficiency at the stack level, Journal of Power Sources, Vol. 292, May 2015, pp. 95-103

[2] P. Piela, J. Mitzel et al., Performance Optimization of Polymer Electrolyte Membrane Fuel Cells Using the Nelder-Mead Algorithm, submitted to Journal of Power Sources