

# Implementation of a Non-Discretized Multiphysics PEM Electrolyzer Model in Modelica®

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## Abstract

This paper outlines the development of a multi-physics model of a proton exchange membrane (PEM) electrolyzer with selectable physics submodels in Modelica®. The Hamburg University of Technology is currently conducting research on coupled power, gas, and heat grids using software models written in Modelica in hopes of increasing the efficiency of these systems. The TransiEnt Library is an open source Modelica library of components for modeling coupled energy networks with high shares of renewable energies (Hamburg University of Technology, 2018). The electrolyzer model outlined in this paper will be included in the TransiEnt Library to increase the scope of studies on energy storage for intermittent renewable sources and the coupling of power, gas, and heat grids.

The model is derived almost explicitly from a previous research paper by (Espinosa-López et al., 2018) but uses different models for cooling system power and anode/cathode gas pressures. Some model components were also neglected that appear in other papers, such as concentration overvoltage and mass transport due to diffusion, since they do not significantly affect industrial electrolyzers under normal operation. The cooling model is implemented using a feedback controller connected to a RealOutput, which can be connected to an external model to utilize waste heat if desired. The hydrogen pressure is kept constant for simplicity in the validation of models in this paper, but can be connected to a dynamic model if desired. Categorized physics submodels of voltage, pressure, temperature, and mass flow models allow users to define their own models if desired. This also allows for the library to be updated with ease with evolving research models. There is also a Specification record that contains system specific parameters for any electrolyzer configuration, such as thermal capacitance and activation energy required for proton transport in the proton exchange membrane. Most of these parameters can be found using the procedures outlined in (Espinosa-López et al., 2018). Shared variables and parameters are declared using the Modelica modifiers `inner` and `outer` to allow for interconnectivity between the submodels.

The electrolyzer model is validated against the experimental results in (Espinosa-López et al., 2018) with minimal error in behavior. The most noticeable differences are between the working temperatures of the models during simulation, which can be explained by the alternative implementation of the temperature and pressure models. These models can vary quite widely from system to system regardless.

The model is suitable for a new study, which is performed using wind speed records from a wind farm in northern Germany to estimate the potential power generation and corresponding amount of hydrogen produced over the course of one year. The results show that one Vestas112-3.0MW wind turbine generated the potential power to produce 1.906 tonnes of hydrogen gas in 2015 at the Wwroh-Osterrade wind farm with the electrolyzer system from (Espinosa-López et al., 2018). The average energy conversion efficiency is 75.3% using the net calorific value of hydrogen combustion. This is enough hydrogen to fill approximately 400000 tanks of the Toyota Mirai, a fuel cell powered sedan. The electrolyzer model has great potential for further studies in applications such as overload operation or waste heat recapture and reuse.

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## References

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