Model-based development of controller strategies for domestic fuel cell cogeneration plants

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Motivation

Domestic fuel cell heat/electricity cogeneration plants, fuelled with natural gas, are presently promoted as one of the most efficient solutions to reduce the CO_2 emissions of private households. These small systems including a gas reformer, a fuel cell stack and an auxiliary burner are dimensioned to fulfill the heating and warm water demands of a building (by hundred percent in the winter case). Considering the electric efficiency, the thermal load, the dimensions of the storage unit and the user behavior, the situation is similar for the accumulated electric load of a building. Energy supply companies recognize this way of cogeneration as an opportunity to open up the heat market. ”Virtual power plants” as a result of these distributed power stations are seen as an important part in the future grid structure.
Depending on the energy load (heating/warm water and electricity demands), the dimensions of the installed storage unit and possible dynamic pricing concepts, different controller strategies are possible, optimizing the CO_2 emissions and/or the financial profits. Within the NEGEV R&D project (new energy concepts for buildings), coordinated by the Fraunhofer ISE, such energy management strategies are developed, evaluated and optimized. In this paper the control strategies and their results will be presented. Therefore numerical simulations are carried out for a time base of one year, using the data for a ”low energy consumption house” monitored by the German utility EnBW.

Simulation environment

The model-based development, evaluation and optimization of controller strategies is realized with the simulation environment ColSim. Originally developed at the Fraunhofer ISE to calculate solar thermal systems, ColSim now offers recent models to simulate fuel cell cogeneration plants and their controller systems in the HVAC building environment. Therefore the library includes models for fuel cell stacks, reformers, power inverters, heat storage units, pumps, compressors, valves and controllers. Using so-called ”plug-flow modeling” and a modified Euler algorithm to solve the differential equations, time steps in the range of seconds are feasible. In spite of using small time steps, the data for one year are processed on a modern Linux PC in about one hour. This offers the possibility to develop controller algorithms (controllers for components and controller strategies) in the simulation environment. All models and control sequences are implemented in ANSI-C, whereby the developed algorithms can be ported onto the controller hardware. Beyond that, the modular concept of ColSim allows the energy evaluation of different system concepts. Interactions between single elements, for example the cooling circuit of the fuel cell stack and the storage unit, can be taken into account and will be presented in the article.