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SOLID OXIDE ELECTROLYZES SYSTEM DEVELOPMENT

Richard SCHAUPERL[1], David REICHHOLF[1], Jürgen RECHBERGER[1]

Summary

Various advantageous system concepts for SOEC, Co-SOEC and rSOEC systems including all components which are necessary to operate the high temperature electrolysis stack, were identified. Validated system concepts on the test rig will be presented, reaching electrical to chemical energy conversion efficiencies up to 80 %.

Abstract

Power-to-Gas-to-Power technologies offer strong potentials for energy markets with highly stochastic energy production from renewable sources, such as wind and PV. Electrical energy can be stored in chemical energy by producing molecular hydrogen or syngas. This happens via electrolysis of steam or co-electrolysis of steam and carbon dioxide. These energy carriers can either be used as a buffer for fluctuating energy production or used as transport fuels. The synthetic fuels are potentially carbon neutral, when the electricity comes from renewable energy production.

Increasing efficiencies and cost effectiveness are key issues in state of the art solid oxide electrolyzes systems and still a major challenge. A very cost-effective solution is using instead of two separate units that operate alternately for gas or power production, a reversible SOE system (rSOE). The rSOEC system can switch between these two operation modes, which results in a more compact system that can be operated almost full time. Additionally, the system can be highly efficient operated with a whole range of different fuels, which increases the technologies flexibility and usability.

This multiuse and multifuel character of SOE systems leads to very particular challenges in the development. A feasible concept has to combine all necessary BoP components and control mechanisms allowing all modes of operation, while keeping efficiencies and cost effectiveness. One particular challenge for the system design is heat management. A method was developed that promises best possible use of heat recirculation in all modes, while being minimal in design and regulation requirements. For the first-time dynamic simulations for all operating conditions e.g. start-up, shut-down, stand-by and mode-switching processes, including all relevant mass and energy flows are currently developed. This strongly supports the system development by making them more effective, since iterative development circles and thus development time and hardware costs were reduced.

The project “Hydrocell” (2013-2016) demonstrated the usability of these simulation methods. A Proof-of-Concept SOEC system has been developed and tested with electricity to H_2 (LHV) conversion efficiencies above 80 $\%_{el}$.

Within the project “AuRora” (2016-2018), various system designs for a fully autonomous rSOE system were identified. The concepts are switchable between H_2O electrolysis, H_2O+CO_2 co-electrolysis with system integrated catalytic methanation and multifuel SOFC operation. System concepts are developed with conversion efficiencies above 80 $\%_{el}$ for H_2 production and CH_4 production. Based on the simulation results, including CFD, a 1 kW_{el} Proof-of-Concept will be realized on the testrig in 2018.

Within the presentation, the theoretical background, different SOE and rSOE systems designs, optimized operation conditions, as well as system measurements performed in the project “Hydrocell” and “AuRora” will be explained. This includes steam-electrolysis, H_2O + CO_2 co-electrolysis with system integrated catalytic methanation, SOFC operation with H_2, as well as multifuel operation with system integrated fuel reformation. The actual flagship project “HydroMetha” (2018-2021) will be presented, where a novel, fully integrated system of CO_2+H_2O high-temperature co-electrolysis (Co-SOEC) and catalytic methanation will be developed.

[1] AVL List GmbH, Hans List Platz 1, Tel.: +43 316 787-2168, Fax: +43 316 787-3799, richard.schauperl@avl.com, www.avl.com