Simulative and experimental investigations of transient operating behaviour of SOEC reactors with multiple stacks for syngas production

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Summary.

Due to the high operating temperatures of SOCs (Solid Oxide Cell), complex test rig set-ups and SOC's high thermal masses, the experimental investigation of SOC reactors with multiple stacks is challenging. This study proposes a methodology to find optimal operating conditions of an SOC reactor with the use of a transient computational model, for syngas (H_2+CO) production.

Abstract.

Despite the increment in greenhouse gas emissions and global warming, current global energy demands are still relying on the usage of fossil fuels. Adopting hydrogen and syngas as a form of energy carrier can be leveraged as a major step towards defossilization of modern society, regardless of an increase in the current energy demands [1]. Electrochemical production of molecules using green electricity and co-electrolysis of steam and carbon dioxide could become a relevant path to obtain syngas, which is a key feedstock for several applications [2]. High temperature SOC systems can produce these gases with highest process efficiency. In order to play a significant role in the future energy system, green syngas production must be scaled into the multi MW range.

At the German Aerospace Center (DLR) a test environment for SOC reactors with multiple stack was built, for an electrolysis power of up to 150 kW. Additionally, an in-house simulation framework that allows to replicate the physical behavior of a SOC reactor was developed [3]. One of the challenges of co-electrolysis operation is to find optimal operating conditions at high reactant conversion. Such investigations require cost-intensive test rig set-ups and are time-consuming. In addition, commercially available reactors are not suitable for research, since the number of sensors installed is not sufficient to analyze operating conditions. In order to study and predict different operating conditions in a time efficient manner, the simulation framework can be utilized.

In this contribution, it is shown how a model of a SOC reactor with 24 stacks can be used to support the experimental investigation on that reactor. By using the simulation's thermoneutral and isothermal operating points, various syngas ratios are predicted. These are in turn used as inputs for the experimental investigation. Results from both simulation and experimental co-electrolysis operation are shown in detail, with a syngas ratio in the range of 2–4. During the experiment, the stack temperatures had a maximum offset of 5 K compared to the predicted values via the simulation, for the same operating conditions. This approach has led to a more efficient experimental investigation process, as well as to a significant amount of experimental time saved per each operating point. Analyses of operating behaviors and strategies will be presented to showcase how the synergy between the simulation framework and experimental test protocols significantly contributes to the upscaling of SOC reactors.

[1] K. Mazloomi, C. Gomes / Renewable and Sustainable Energy Reviews 16 (2012) 3024–3033
[2] Sternberg, André; Bardow, André (2015). Power-to-What? – Environmental assessment of energy storage systems. Energy Environ. Sci., 8(2), 389–400. doi:10.1039/c4ee03051f
[3] Marius Tomberg et al 2019 ECS Trans. 91 208