Process Design Study of reversible Solid Oxide Cell (r-SOC) system for coupling Energy Storage and Hydrogen economy supply chain

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Abstract

Higher penetration of renewable energy sources in the energy mix and increasing pressure to decarbonize society introduces new challenges. Energy storage and grid stabilization systems are necessary to address the intermittent nature of renewable energy sources (wind, solar etc.) [1]–[4]. Renewable energy storage in form of hydrogen offers an attractive option for energy storage [5], [6]. With advent of hydrogen economy and growing number of fuel cell vehicles, local production and supply of hydrogen infrastructure for refueling stations is essential [7]–[9].

An r-SOC electrochemical reactor system is capable addressing these multiple challenges of energy storage and coupling the energy storage sector with hydrogen economy sector. Electricity storage is achieved by operating such a system in electrolysis mode (reduction of H_2O). Electrical energy is converted to chemical energy in form of hydrogen. The produced hydrogen can be supplied into gas grids or stored locally which can be supplied to hydrogen refueling stations. During high demand for electricity, the system can be switched to fuel cell mode during which the stored hydrogen is efficiently converted to electricity. r-SOC systems offer an interesting feasible solution for the following challenges: 1) Efficient electricity storage, 2) Grid stabilization required for intermittent renewable energy, 3) Sector coupling of energy storage sector with hydrogen economy supply chain and 4) A decentralized solution for the above challenges via e.g. hydrogen refueling stations.

An r-SOC system as described above poses certain technical challenges as requirements of a stand-alone SOEC (solid oxide electrolysis cell) system and a stand-alone SOFC (solid oxide fuel cell) system are different from each other. The simplest design approach for an r-SOC system calls for thermoneutral or exothermic electrolysis

operation, although this will yield low round trip efficiencies in the range of 35 % [10]. Coupling highly efficient endothermic electrolysis and exothermic fuel cell mode allows for significantly higher round trip efficiencies up to 60 %. Therefore thermal integration, storage and management between the two modes of operation are crucial. In this study, a process system study of an r-SOC electrochemical reactor system is performed. Process system analysis is performed based on experimental investigation of a commercially available r-SOC reactor carried out under pressurized conditions. Opportunities of integrating thermal energy storage are investigated. Detailed process system architectures are discussed and effects of key system operating parameters are analyzed. Achievable system roundtrip efficiencies for the different scenarios using currently available r-SOC reactor technology are quantified.

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