ANALYSIS OF REVERSIBLE SOLID OXIDE CELL TECHNOLOGY FOR GRID-ENERGY STORAGE AND SYNTHETIC NATURAL GAS PRODUCTION WITH CO_2

Evan Reznicek, Department of Mechanical Engineering, Colorado School of Mines, Golden, CO USA
Robert Braun, Department of Mechanical Engineering, Colorado School of Mines, CO USA
ereznice@mymail.mines.edu

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Reducing electricity related carbon emissions requires movement toward renewable energy technologies such as wind and solar, which is challenging due to their inherent intermittency. Electrical energy storage (EES) is expected to play a critical role in enabling greater penetration of renewables, but current technologies suffer from capacity limitations and high cost. Reversible solid oxide cells (ReSOCs) are an electrochemical energy conversion technology that can provide high efficiency and cost effective storage at both distributed and grid scales. This presentation discusses the fundamentals of ReSOC operation and compares the performance, cost, and net carbon emissions of ReSOCs employed in traditional EES systems with that of ReSOCs integrated with natural gas pipeline infrastructure and captured carbon dioxide.

ReSOCs are ceramic electrochemical devices that can be used to either produce power from fuel when electricity is needed (fuel cell mode), or produce fuel from electricity when excess energy is available (electrolysis mode). By leveraging C-O-H reaction chemistry and operating at intermediate temperatures (600^{o}C), these cells can be mildly exothermic in both operating modes, eliminating the need for external heat input or high over-potential operation during electrolysis. Storage of fuel (H_2, CO, CH_4) and exhaust (H_2O, CO_2) in tanks at the distributed scale and large caverns at the grid scale allows ReSOC systems to provide stand-alone EES services. While previous work has quantified performance and cost of ReSOC energy storage systems at both distributed and grid scales, this work focuses on ReSOC systems that couple natural gas pipelines as a fuel source and captured carbon dioxide as a co-electrolysis feedstock. ReSOCs are well suited for both carbon capture and synthetic fuel production. In fuel cell mode, ReSOCs consume fuel and oxygen and produce water, CO_2, and excess air. Because fuel oxidation occurs via oxygen transport across the ReSOC electrolyte, separation of carbon dioxide from the exhaust stream can be achieved without concern for nitrogen. In electrolysis mode, internal methanation can be promoted to both provide heat for co-electrolysis of water and CO_2 and to produce methane. Coupling ReSOC systems with natural gas pipelines and piped or tanked CO_2 allows for both electricity generation with carbon-rich exhaust and for scalable carbon utilization given a source of CO_2 and excess renewable electricity.

However, it is unclear how such a system should be designed and operated in order to provide cost competitive electricity and synthetic natural gas, while maintaining low net carbon emissions. This work explores system design concepts, performance, cost, and net carbon emissions of a 50 MWe ReSOC system integrated with natural gas pipelines and stored CO_2, and compares to ReSOCs used as flow-battery energy storage systems. Preliminary modeling results predict a fuel cell mode LHV efficiency of 56%, an electrolysis mode LHV efficiency of 62.6%, and system cost of 700$/kW. Additionally, it is observed that the stack and air-side components (heat exchangers, compressors, expanders) can be compatible in both modes of operation, reducing cost. The compatibility of condensers, heat exchangers, and compressors used for fuel and exhaust processing, however, depends strongly on the relative pressures of natural gas and carbon dioxide sources and sinks. Additional ways of reducing cost and net carbon emissions are also investigated and presented.