Reversible Operation of Solid Oxide Cells for Sustainable Fuel Production and Solar/Wind Load-Balancing - DTU Orbit (10/08/2019)

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The solid oxide electrochemical cell (SOC) is a promising candidate for large-scale energy storage. In electrolysis mode it stores renewable electricity as chemical energy in the form of fuels like hydrogen and hydrocarbons, and the same cell can be operated in the reversed direction to produce electricity from fuels – either previously stored fuels or from an external supply e.g. natural gas or biogas. This reversibility combined with fuel-flexibility is unique among energy storage technologies like closed-system batteries and single-direction electrolyzers. However, few studies have been conducted with focus on fundamentals or applications of bi-directional operation. This presentation will highlight our recent developments in applying reversible SOCs (RSOCs) for renewable energy storage with respect to cell and stack testing, cell and system design, and techno-economic analysis. At the cell level, long-term testing has shown that improved stability can be achieved by reversible operation compared with steady-state electrolysis operation. Further, we have developed novel Ni-free fuel-electrodes that both outperform conventional Ni-based electrodes and do not catalyze carbon deposition, which opens the door to advanced applications of RSOCs that utilize carbonaceous fuels. At the stack level, we have demonstrated operation that follows real-world time-series electricity supply and demand data, considering a 100% renewable energy scenario where wind power is the only power supply. When the wind power supply exceeds demand, the RSOC stack produces syngas via co-electrolysis of CO2 and H2O. Part of the syngas is converted to methanol downstream in the system to meet the demand of transportation vehicles, and the rest is stored for electrical load balancing by conversion back to electricity in fuel cell mode when electricity demand exceeds the wind power supply. At the system level, techno-economic analyses and system designs for different scales and applications have been realized. A simulation of an RSOC system that uses real-world time-series market prices for electricity and natural gas in Denmark to decide when to cooperate in electrolysis mode (buying electricity and selling methane) or fuel-cell mode (buying gas and selling electricity) shows the advantage of a reversible system and the changing operating profile as the fraction of wind power supply grows. Finally, we discuss the potential for systems with novel chemistries and components to compete with state-of-the-art rechargeable batteries with respect to cost and round-trip efficiency.

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