II.I.8 Development of a Hydrogen Home Fueling System

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Objectives

- Define the requirements for hydrogen home fueling system needs.
- Design and optimize process flows for the hydrogen home fueling system.
- Implement DOE's H2A model to analyze the tri-generation economics and identify barriers to be overcome.
- Setup a technology development plan to advance home application of the technologies.

Technical Barriers

This project addresses the following technical barriers from the Production section (3.1) of the Fuel Cell Technologies Program Multi-Year Research, Development and Demonstration Plan:

(G) Capital Cost

(H) System Efficiency

Technical Targets

Verify feasibility of achieving \$3.70/gasoline gallon equivalent (gge) (delivered) from distributed electrolysis (4Q, 2012).

Accomplishments

- Completed analysis of fuel-assisted electrolysis home fueling station process design.
- Showed that using current technology, with current production methods and supply costs, a gge cost of \$8.73 can be achieved, with feedstock costs of \$1.65/gge.
- Constructed a solid-oxide fuel-assisted electrolyzer and power production hybrid module and used the resulting performance data as input to the home fueling station process design.
- Identified safety codes to be modified for hydrogen home fueling station applications.

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Introduction

A critical factor inhibiting the rollout of hydrogen vehicles is the lack of supporting hydrogen distribution and generation networks. Significant use of hydrogen vehicles is not feasible until convenient fueling is accessible to the driving public; a possible solution to this problem is the simultaneous rollout of both hydrogen vehicles and home-based (distributed) hydrogen generation. For such a system to be economical, and avoid the problems associated with on-site hydrogen production via reformation, a fuel-assisted electrolysis method can be used–pairing the purity of electrolysis generated hydrogen with the reduced cost of natural gas feedstock (replacing high cost of the electricity requirement).

Approach

In this project, several system process designs were completed for a hydrogen home fueling system using solid-oxide fuel-assisted electrolyzer cell (SOFEC) technology. Small hybrid SOFEC/solid-oxide fuel cell (SOFC) power generation modules were fabricated and tested, and the performance data were fed into the system process designs to ensure accuracy in the performance component of the cost modeling. The most cost-effective and efficient process was chosen and analyzed for major contributors to the calculated distributed hydrogen production cost.

Results

In conjunction with NREL, MSRI completed a system process design which calls for the use of distributed natural gas as a depolarizing agent to reduce the electrical cost of high-temperature steam electrolysis.

Important considerations in the completion of this design were: (a) projected demand for a fuel cell vehicle operating as a daily commuter, (b) performance of the hybrid SOFEC-SOFC modules, (c) the expected "charge time" allowable (a longer term hydrogen generation cycle allows for reduce system size and correspondingly reduced operational and capital costs), (d) planned operational lifespan of the hydrogen fueling appliance, (e) amount and cost of feedstocks, (f) operational behavior, including system shutdown/startup behavior, expected turndown, required user interaction, etc., and (g) expected subsidiary roles (power and/or heat generation).

Hybrid SOFEC-SOFC (hydrogen and power cogeneration) stacks were built and run using distributed natural gas (directly from the Questar Gas residential/commercial network) and a performance profile was established for the technology at its present state. The data (including performance at a variety of fuel and air utilizations and amperage levels) were compiled and fed into the process design to allow performance analysis according to the H2A model. Figure 1 shows a selection of the performance profiles obtained through the module testing at various utilizations, and Figure 2 shows a steady-state performance profile with set utilizations.

The completed process design included all the requisite components for a hydrogen generation system, including an autothermal reformer, a steam generator, heat recovery devices, hybrid SOFEC/SOFC (hydrogen/power generation) modules, condensers, and a hydrogen compressor. Analysis of the design allowed a current state of technology cost per gge estimate to be made (see Figure 3); it is clear that to meet DOE targets, capital costs (adding \$4.51/gge to the production cost) must be reduced significantly.

Conclusions and Future Directions

Hydrogen production via SOFEC has shown to be a viable means of significantly reducing the operational costs of hydrogen generation via electrolysis. It is also clear, that in order to meet the cost goals established by the DOE it will be necessary to reduce the unit capital cost. In addition, a review of existing residential and commercial codes has shown that the regulatory structure necessary for the widespread implementation of residential hydrogen fueling stations is not yet in place.

Future work will include:

- The completion of a complete proof-of-concept hydrogen production unit (including balance-of-plant components).
- Characterization of the complete unit, including the development of practical and optimized startup, shutdown and steady-state operation.
- Recommendations on how the hydrogen home fueling unit can fit into regulatory code development efforts.
- A design for manufacture analysis targeting significantly reduced unit production cost.

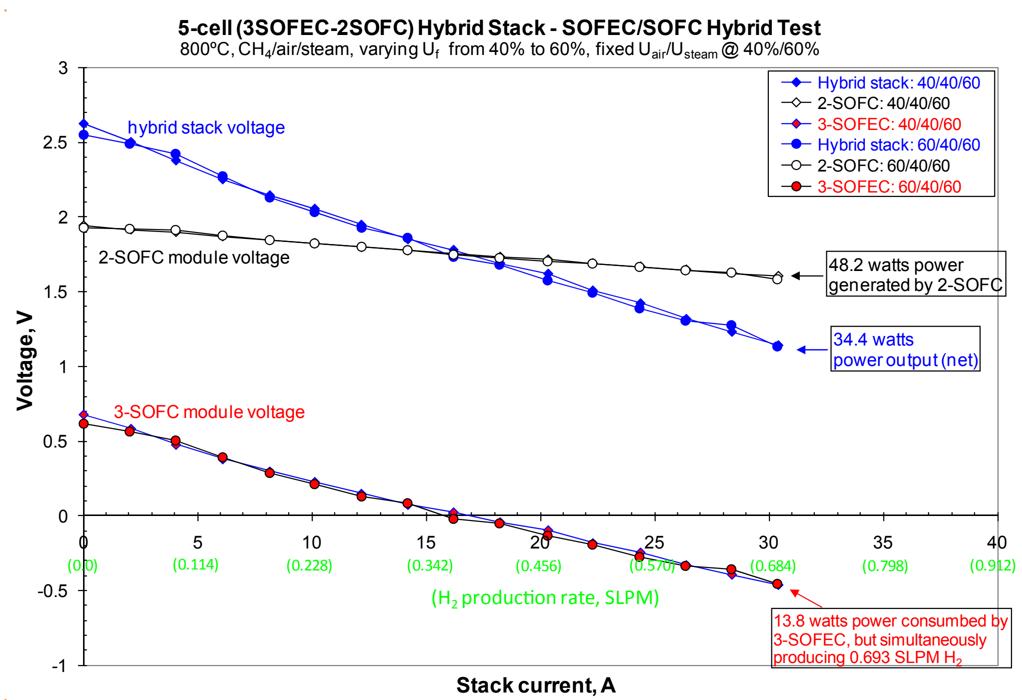

FIGURE 1. Utilization Specific Performance in Hydrogen and Power Co-generation Mode

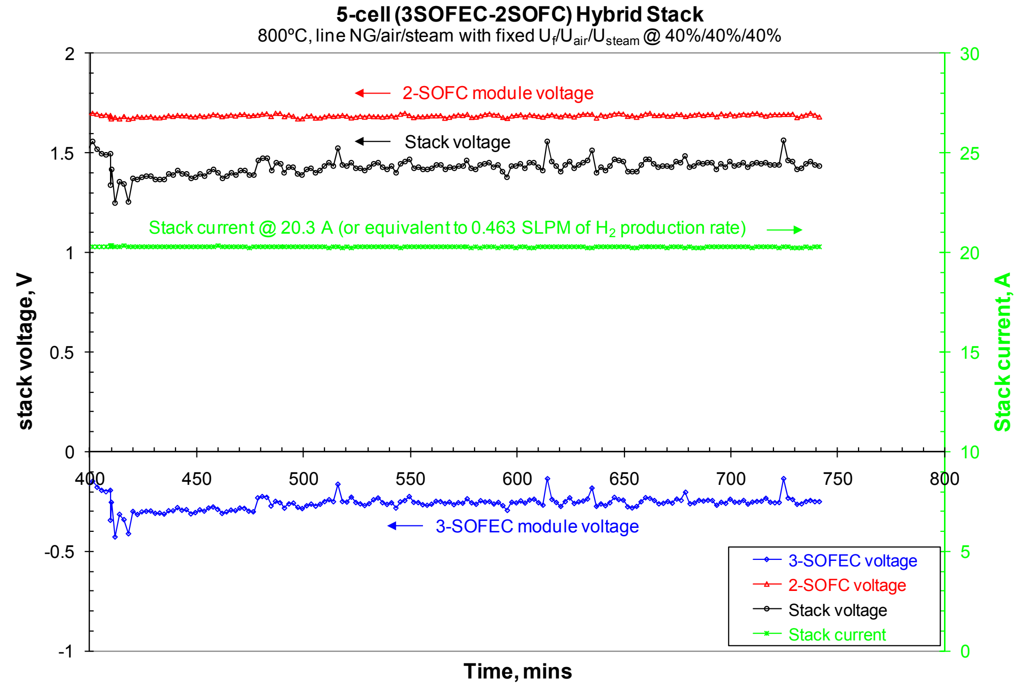

FIGURE 2. Steady-State Hybrid Module Performance

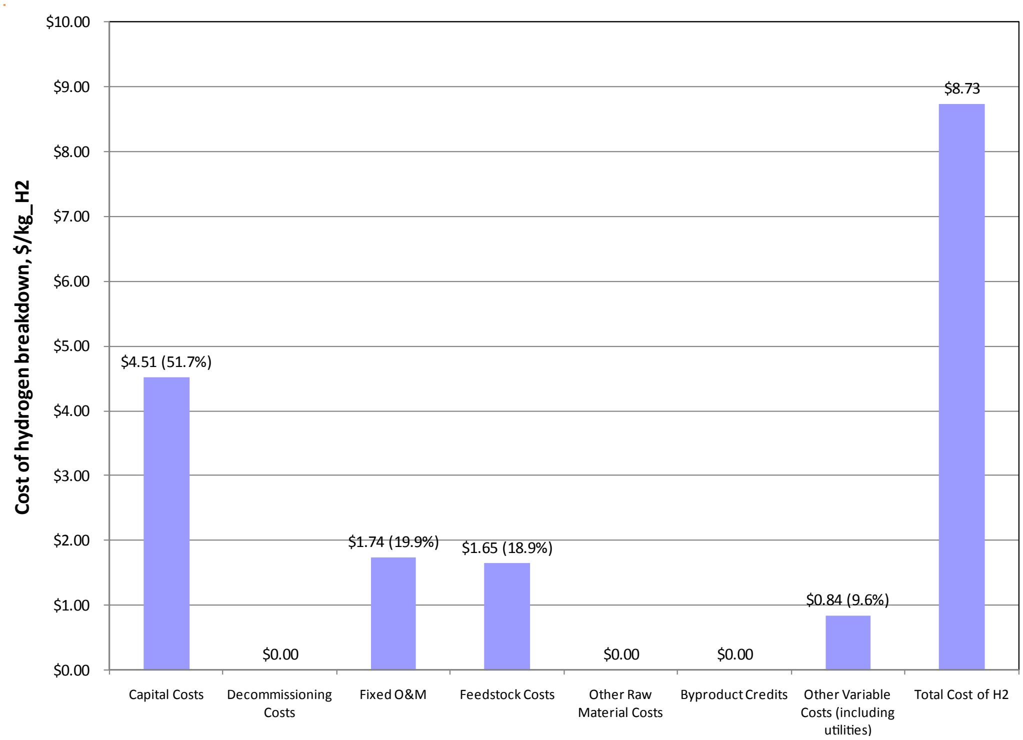

FIGURE 3. Solid-Oxide Fuel-Assisted Home Hydrogen Fueling Cost Breakdown

FY 2010 Publications/Presentations

1. G. Tao, B. Butler, and A. Virkar, "Development of a Hydrogen Home Fueling System", 2010 AIChE Annual Meeting, Nov. 7-12, 2010, Salt Lake City, UT.