V.G.3 Intergovernmental Stationary Fuel Cell System Demonstration

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Objectives

- To design and produce an advanced prototype proton exchange membrane (PEM) fuel cell system with the following features:
  - 5 kW net electric output.
  - Flexible-fuel capable–liquefied petroleum gas (LPG), natural gas, ethanol.
  - Reduce material and production cost and increase system and stack durability.
  - Increase electrical efficiency over the existing GenSys 5U48 design.
  - Increase total system efficiency by incorporating combined heat and power (CHP) capability.
- To show a path to meet long-term DOE objectives:
  - 40% system electrical efficiency.
  - 40,000-hour system/fuel cell stack life.
  - $750/kW integrated system cost (with reformer).
  - $400/kW fuel cell stack cost (direct hydrogen).

Technical Barriers

This project addresses the following technical barriers from the Fuel Cells section (3.4.4) of the Fuel Cell Technologies Program Multi-Year Research, Development and Demonstration Plan:

(C) Performance

(B) Cost

(A) Durability

Technical Targets

Integrated Stationary PEM Fuel Cell Power Systems (5-250 kW) Operating on Reformate

This project conducted fundamental analysis and demonstration of fuel flexible (ethanol/LPG) CHP integrated system. Results of the system design have shown the ability to meet the following DOE 2011 targets:

- Survivability (min and max ambient temperature) -35 to +40°C
  - Successful system operation shown from -40 to +46°C
- Noise < 55 dB(A) @ 10 m
  - Measured noise emissions of <60 dB(A) at 3 m at rated power at nominal ambient conditions which when applying the inverse square law equals 49.5 dB(A) at 10 m.

Learning gained from work activities of this project will be applied toward the design and manufacture of a system that is on a path to meet the following DOE 2011 targets:

- Durability at <10% rated power degradation: 40,000 hours
- Cost at 2,000 units/year: $750/kWe
- Performance (target values adjusted to account for LPG-fueled system)
  - Electrical efficiency at rated power: 38.5%
  - CHP efficiency at rated power: 78.5%

Accomplishments

- Completed the analytical and design work necessary for the prototype system, received a "go"decision from DOE for the next phase of the project.
- Completed the fabrication and assembly of the prototype system and began system integration testing.
- Achieved system material cost reduction of 53 percent (in production quantities) when compared to prior year's system material cost roll-up.

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Introduction

Long-term commercial acceptance of PEM-based fuel cell systems is contingent on reducing the material and operating costs and improving the durability of the system and its components. The current technologies employed for PEM fuel cell stacks and the uniqueness of other system components contribute significantly to the material cost of the system.

This project is not only advancing the state-of-the-art of PEM fuel cell technologies, but also established an integrated, low-cost, flexible-fuel reformer for on-site fuel cell power generation. These achievements, in turn, helped to enable commercialization of the technology by improving economic feasibility and providing multiple fuel options for a variety of commercial applications. This project included the design, manufacture, test and field demonstration of a CHP, grid-connected fuel cell system. The resulting system advanced the state-of-the-art toward the DOE's program objectives of increased durability, reduced cost and improved efficiency.

Approach

- Concept Development (100% complete)
  - Go/No-Go: Concept design review
- System Definition (100% complete)
  - Go/No-Go: System interface review
- System Integration (100% complete)
  - Go/No-Go: Field readiness review
- Prototype Field Demonstration (85% complete)
  - Construction Engineering Research Laboratory unit demonstration rolled into 7A project using commercial GenSys unit.
  - Demonstration currently being conducted at Union College Beuth House, Schenectady, NY, using commercial GenSys unit.
- Project Closeout (90% complete)

Results

Demonstration

Plug Power installed a GenSys Blue high-temperature PEM fuel cell system at Union College Beuth House in Schenectady, NY. This includes field readiness design, build, shipping, installation, commissioning, demonstration, decommissioning, site restoration and public/end user education. The system continues to run, logging 1,436 hours since commissioning, and is continually evaluated.

Stack Sourcing

The original project intent was to leverage Plug Power's supply chain and knowledge gained during Topic 3.1 work activities at Warner Robins Air Force Base (which led to development of the "Rev 3" membrane electrode assembly, MEA), and expand to a fuel cell stack solution capable of meeting both DOE objectives and those required for productization.

Based on preliminary work on the TeleCOOP project, Plug Power and Ballard proceeded to collaborate. However, stack integration complications occurred with the commercially available Ballard MK-1300 series stack design and DOE goals were not met. These complications included: high pressure drop posing issues finding applicable balance-of-plant components, high differential pressure posing issues in controllability of the system, and system efficiency and turndown capability being negatively impacted by the stack design.

Improvements made by 3M in durability and cost, and leveraging the production design MEA, confirmed the viability of a Plug Power/3M stack solution from a material cost and superior system design perspective.

Stack Sourcing Pressure Drop

The commercially available stack had up to 3.5x the pressure drop of the Plug Power stack design. The higher pressure drop required for the water management method led to lower system efficiency and difficulty finding components to supply the required reactants. Low power efficiency was also affected due to "differential pressure floor."

Stack Sourcing Efficiency Impacts

The efficiency impact of the commercially available stack negated any potential gains it had in cost and durability. The GenSys 6U48 product advantage over incumbent technology is based on superior efficiency leading to op-ex savings. The commercially available stack was not a viable solution for a GenSys product and did not show a path to meeting DOE objectives.

Low-Temperature PEM for CHP Applications

Using a low-temperature PEM system in a CHP application has been studied for both the maximum heat recovery and maximum output temperature based on the existing design. 8,200 W (28,250 BTU/hr) are available at a temperature of 65°C (150°F) and the maximum outlet temperature of 77°C (170°F) is possible with 5,050 W available. Further improvements in quality of heat are possible at the expense of electrical efficiency and Plug Power is investigating the viability of a low-temperature CHP system based on the GenSys system architecture.

System Material Cost

Material cost of the GenSys system has been reduced by 63 percent due to design activities related to this project. Fuel cell stack material costs were reduced 59 percent and an additional 15 percent cost reduction is expected once the design is fully tooled.

Reliability Improvements Startup Sequencing

In an effort to combat carbon corrosion on the MEA during H_2/air front propagation at start-up, various system controls approaches were studied. Results of these tests proved that a controls and isolation solution existed that was much less costly than an MEA materials solution. This allowed reduction in MEA loading, leading to a lower overall cost.

Reliability Improvements Cathode Humidification

Several different types of cathode humidifiers were studied with the goal of reducing part cost while maintaining a high cathode saturation for increased stack life. The outcome from these tests resulted in qualification of a part that was approximately 50 percent of the cost of the incumbent, with improved levels of humidification across the operating range.

Conclusions and Future Directions

The Union College unit will be decommissioned in the summer of 2011. Due to significant system advancements, DOE has agreed to close out the 7C project and roll the Construction Engineering Research Laboratory contract obligations into the 7A project. Under the 7A project Plug Power will provide data to the Construction Engineering Research Laboratory from one of the 20 systems to be installed at Warner Robins Air Force Base in Georgia.

FY 2010 Publications/Presentations

1. 2010 DOE Hydrogen Program Annual Merit Review, (Presentation FC057), Washington, D.C. June 2010.