IV.G Stationary Power Systems

IV.G.1 Advanced Buildings PEM Fuel Cell System

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Objectives

- To demonstrate high electrical and overall efficiency, reduced energy consumption, and reduced emissions for hotel applications.
- To overcome technical and cost barriers through the engineering, design, and construction of an integrated fuel cell system utilizing advanced subsystems including the fuel cell stack, the fuel processor, and balance of plant components.
- To validate a 50-kW proton exchange membrane (PEM) fuel cell system design through field testing at three separate hotel properties.
- To use the information provided from this demonstration to target early market entry opportunities.

Technical Barriers

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

- E. Durability
- F. Heat Utilization
- G. Power Electronics
- J. Durability
- K. Emissions
- L. Hydrogen Purification
- M. Integration and Efficiency
- N. Cost
- O. Stack Material and Manufacturing Costs
- P. Durability
- R. Thermal and Water Management

Approach

- Modular development (fuel treatment, fuel processing, fuel cell, thermal recovery, power conditioning)
- Steam methane reforming

- High-efficiency pressure swing adsorption (PSA) hydrogen purification
- Long-life membrane electrode assembly (MEA)
- Efficient thermal recovery

Accomplishments

- Completed functional requirement specifications (FRS) and process flow diagrams for complete system and each sub-module.
- Used accelerated testing conditions in 20-25 cell fuel cell stacks to identify MEA/gas diffusion media combinations showing promise of long-life operation (40,000 hour target).
- Operated proof-of-concept (POC) fuel cell submodule (1/2 system) at 35 kW gross power and 54% net lower heating value (LHV) efficiency. Target for full module is 65 kW.
- Demonstrated lab-scale version of reversible low-cost natural gas desulfurization system for a 6-month equivalent operation.
- Demonstrated 5-kW version of low-cost water treatment system.
- Demonstrated low-emission, 400-kBTU burner and radiation assembly for reformer.
- Initial design of PSA complete (expected operation 8/01/04).

Future Directions

- Demonstrate full-scale (50-kW) POC modules.
- Test and verify POC module performance against FRS document.
- Review POC design for cost reduction measures leading to Alpha Design.
- Begin long-term testing of critical balance of plant (BOP) components.
- Integrate Alpha Modules into complete system for testing and software development.
- Generate manufacturing documentation for Beta systems.
- Deploy three complete systems for 1-year continuous field operation.

Introduction

The objective of the Advanced Buildings PEM Fuel Cell project is to develop a commercial 50-kW combined heat and power system (hereafter referred to as the CM50) offering cost and energy savings to buildings with 50 kW of electrical base load and a steady requirement for hot water. Such buildings include hotels, multi-family dwellings, prison systems, hospitals and others. The underpinning technology for the system is high-efficiency steam methane reforming combined with proton exchange membrane (PEM) fuel cell power production. The long-term promise of these combined technologies is the generation of onsite electricity at an effective rate below $.04 per kWh based on fuel and maintenance costs. The principle challenges for this approach are 1) reducing the capital cost of the system to compete with existing technology on a per-kW basis and 2) achieving long-life operation. The technical barriers identified by the DOE in the Multi-Year RD&D Plan are essentially subcomponents of these categories and are discussed below.

Approach

Development of the CM50 is a four-phase approach comprising a feasibility study, detailed design, manufacturing, and field deployment. The feasibility study has been completed and is reported as three documents: 1) Site Selection Criteria, 2) Functional Requirements Specification, and 3) Process Flow Diagrams. These documents have pointed to natural divisions in functionality and the designation of independently developed modules. The modules include Fuel Treatment, Fuel Processing, Thermal Management, Fuel Cell, and Power Electronics. The design phase of the project (begun 04/01/04) reflects our specific solution to DOE's performance targets (Table 3.4.6 in the Multi-Year RD&D Plan) in areas such as efficiency, rated power, durability, emissions, and cost reduction.

Results

Although the CM50 is early in the design process, several significant accomplishments can be reported in the areas of fuel and water treatment, hydrogen purification, MEA selection, fuel cell power module and fuel processor design.

Water treatment for fuel cell and reforming systems has historically been achieved through reverse osmosis/deionization systems. This solution is effective but adds an estimated $.02 per kWh and requires significant maintenance. An alternative low-cost solution has been demonstrated using continuous blowdown in a distillation unit. A subscale water treatment system has been operated for 1000 hours and maintained product water conductivity below 5 uS. The effective operational cost (efficiency loss from blowdown) is negligible. Periodic vessel cleaning is expected as part of a normal maintenance procedure. This work is being conducted in support of reducing the peripheral consumables to less than $.01 per kWh and improving water management.

Hydrogen purification is accomplished through a pressure swing adsorption (PSA) process. A 5-kW subscale version of the intended configuration has been demonstrated with 75% hydrogen recovery. Hydrogen recovery at the 50-kW scale is expected to increase to 80% through a pressure recovery scheme. This effort will contribute 2% to the electrical efficiency of the system and represents a significant advancement in hydrogen purification in a low-pressure system.

The dominating factor in system life for the CM50 will be the longevity of the membrane electrode assemblies (MEAs) used in the construction of the fuel cell. Optimal combinations of MEAs and gas diffusion media were tested from premiere industry suppliers in head-to-head testing conducted on 20-25 cell stacks under slightly accelerated life conditions (relative humidity of 75% anode / 60% cathode). These tests were

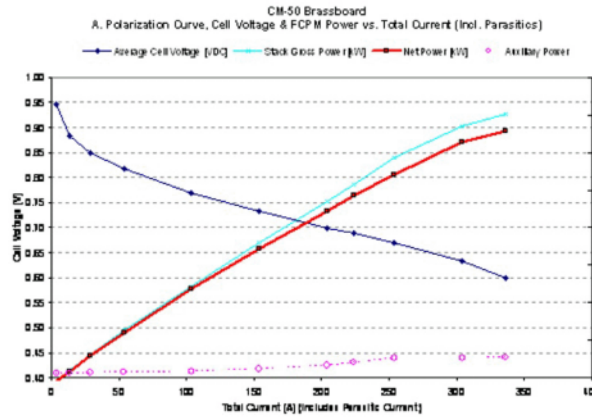

Figure 1. CM50 Power Module Subsection Performance

conducted for 1000 hours and comparisons made for voltage, voltage decay, and fuel cross-over. The best operational performance showed a voltage decay of 6 uV per hour averaged over 1000 hours and no detectible fuel cross-over. This configuration is now under longer-term testing under higher relative humidity (RH) conditions in reflection of expected system conditions. Actual lifetime of this combination is difficult to predict but is expected to exceed 12,000 hours. This effort in conjunction with cost-reduced materials and methods of manufacturing is aimed at the DOE durability barriers.

The 65-kW fuel cell power module consists of two submodules, each housing its own BOP. A POC submodule has been built as an optimization platform for BOP component selection and validation. The designed operational power of the submodule is 32.5 kW, allowing for beginning-of-life stack efficiency of 60%. Peak power for the POC submodule is currently above 60 kW, as shown in Figure 1. Long-term testing of components will address BOP durability concerns.

Progress on the fuel processor has been focused around scaling up the heat transport and catalyst utilization characteristics of an existing 5-kW design. A POC reactor has been designed and is currently under fabrication. The burner section and heat radiator of this design have been operated at full power. Unique characteristics of the design include certification as an ASME pressure vessel.

Conclusions

The Advanced Buildings PEM Fuel Cell System project is in the eighth month of a forty-month project and is transitioning from the feasibility phase, in which the principle objective of system efficiency has been chartered on paper, to the engineering design phase, in which these designs will come to fruition. Interim progress has been demonstrated in the areas of fuel and water treatment, hydrogen purification, MEA selection, fuel cell power module and fuel processor design. Short-term milestones include the characterization of full-scale alpha modules within the next six months.

FY 2004 Publications/Presentations

1. "Advanced Buildings PEM FC Project," by Arne LaVen, DOE Hydrogen, Fuel Cell, and Infrastructure Technologies Program Review Meeting, May 25, 2004, Philadelphia, PA.