V.I.3 Intergovernmental Stationary Fuel Cell System Demonstration

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Subcontractors:

- Construction Engineering Research Laboratory (CERL), Champlain, IL
- Ballard Power Systems, Burnaby, British Columbia, Canada
- Keyspan (National Grid), Brooklyn, NY

Project Start Date: October 1, 2007
Project End Date: April 30, 2010

Objectives

To design and produce an advanced prototype proton exchange membrane (PEM) fuel cell system with the following features:

- 5 kW net electric output.
- Flex fuel capable – liquefied petroleum gas (LPG), natural gas, ethanol.
- Reduced material and production cost and increased durability.
- Increased electrical efficiency over the current alpha design.
- Increased total 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).

Technical Barriers

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

(A) Durability
(B) Cost
(C) Performance

Technical Targets

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

This project is conducting fundamental analysis and demonstration of fuel flexible (ethanol/LPG) CHP integrated system. Results of the current 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 @ <10% rated power degradation: 40,000 hours
- Cost @ 2,000 units/year: $750/kW$_e$
- Performance (Target values adjusted to account for LPG-fueled system.)
  - Electrical Efficiency @ rated power: 38.5%
  - CHP efficiency @ rated power: 78.5%

Accomplishments

- Completed design and analysis tasks necessary to define the components of the system. Prototypical hardware was procured and tested to ensure their capability to meet system requirements.
- Completed system concept design review in June 2008.

- Completed the tasks necessary for the integrated prototype system design including computer-aided design (CAD) modeling, design documentation, bill of materials (BOM) creation, and system integration (Figure 1).
- Completed system detail design review in November 2008.
- Completed the build of prototype system shown in Figure 2.
- Began system integration testing including system controls development and parameter optimization for steady-state and transient operating modes. A sample system response chart is shown in Figure 3.
- Commenced site planning and preparation for system installation at the CERL electroylzer laboratory in Champaign, Illinois (Figure 4).

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

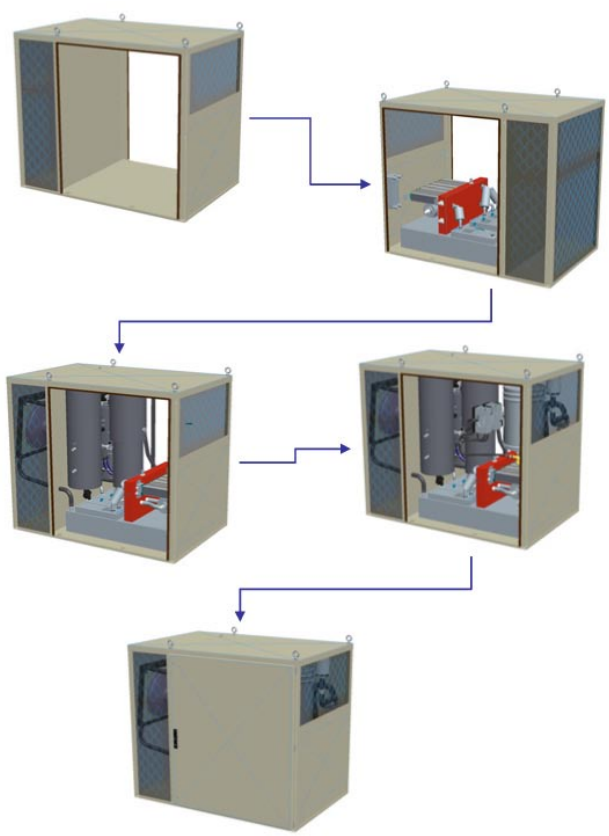

FIGURE 1. Evolution of System Design

FIGURE 2. System Fabrication and Assembly

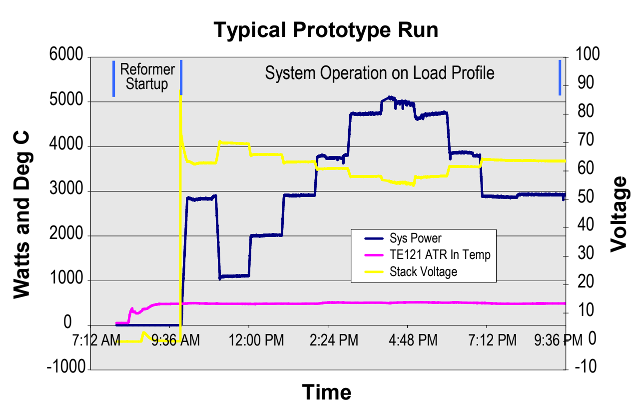

FIGURE 3. Prototype System Operation

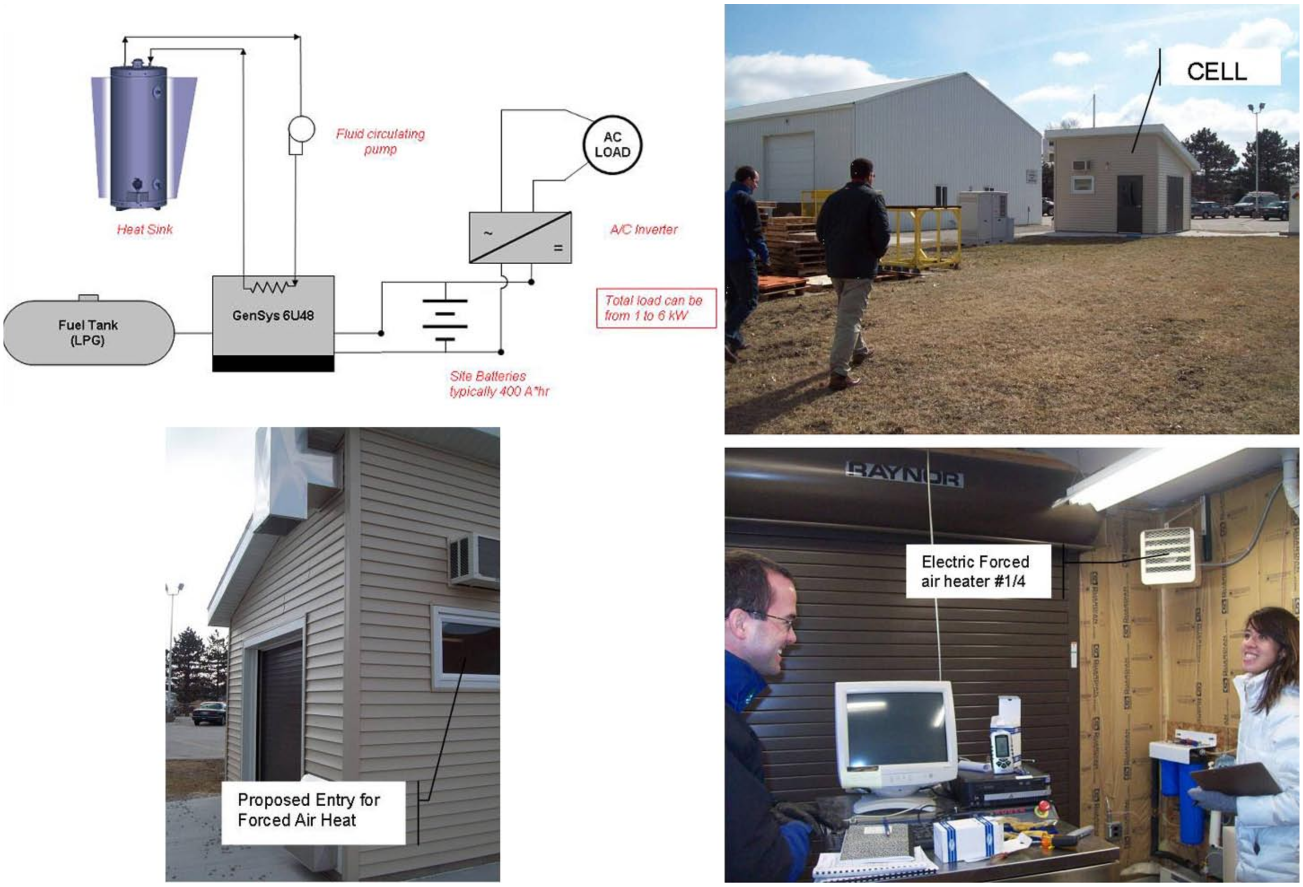

FIGURE 4. Installation Site Planning

Approach

To achieve these objectives Plug Power will use experience in systems engineering and integration gained from over 600 systems installed and operated worldwide to perform concept development and detail design of an ethanol/LPG flex fuel capable fuel cell system that incorporates new technologies necessary to advance toward meeting the DOE 2011 targets for durability, cost and performance.

Results

During the past year Plug Power has completed simulation and modeling of 168 design iterations to optimize system performance and generate component design requirements. The system consists of Plug Power's fourth generation autothermal reformer to generate fuel for a PEM-based fuel cell stack which is coupled with power conditioning equipment to provide regulated alternating current to the end user. The hardware necessary to satisfy this system architecture was sourced and a statistically significant sample of all components was testing to prove their capability of meeting requirements. The project successfully passed a system concept design review in June 2008. A CAD model of the full prototype system was created and the documentation necessary to source the chosen components was created. The components were integrated into a prototype system design and the BOM based on this design was created to perform analysis necessary to project the unit cost in production volumes. The project passed a detailed system design review with DOE personnel in November of 2008. No issues were found and the project entered the build phase. A functional prototype of the design was built at Plug Power's Latham facility in March 2009. During the build, the assembly procedures and system BOM were verified. Once assembled the prototype begin system integration testing to validate functionality. Automated system controls were developed to operate each subsystem and the control parameters were optimized for both steady-state and transient operating modes. Further controls optimization work is still to be done but the system has shown capabilities of efficiency of 32%, approximately 5 points higher than prior vintages of the design as shown in Figure 5.

The planning necessary to install the system at the CERL facility in Champaign, Illinois was started

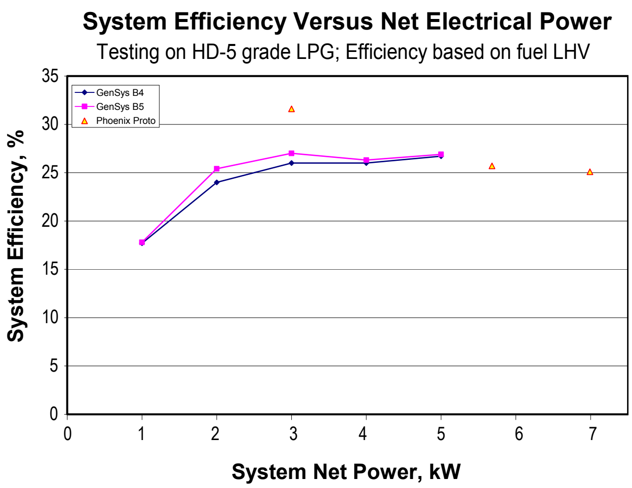

FIGURE 5. Efficiency Comparison

in February of 2009. Once installed the system will provide electric power and heat for CERL's electrolyzer laboratory. Also in the past year the focus of the project has been narrowed to focus only on using LPG feedstock for the reformer. This decision was based on feedback from reviewers received at the annual project review in 2008, and the results of the previous year's work on this project which uncovered economic and logistical challenges of using ethanol as a feedstock. A request was made and accepted by DOE during the September 2008 program review to focus solely on LPG as a fuel for the prototype system installation at CERL.

Conclusions and Future Directions

As a result of activities of this past year Plug Power was able to design and build a prototype fuel cell system which shows good progress toward meeting DOE's 2011 goals. Successful system operation has been achieved and the work necessary to show that the resulting production design is commercially viable has been completed. Planning is underway for the prototype system to be installed and commissioned at the CERL facility later this year.

For the remainder of the project we have defined the following tasks necessary to bring this project to a successful conclusion.

- Remainder of 2009:
  - Complete design verification testing.
  - Conduct field readiness review.
  - Complete site planning and system installation.
  - Commission prototype system and commence field operation and support.
- Fiscal Year 2010:
  - Complete field operation and support.
  - Decommission system.
  - Post demonstration testing.
  - Project close out.