XII.12 Highly Efficient, 5 kW CHP Fuel Cells Demonstrating Durability and Economic Value in Residential and Light Commercial Applications

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Contract Number: DE-EE0000480

Subcontractor:
University of California, Irvine (UCI), Irvine, CA

Project Start Date: October 1, 2009
Project End Date: September 30, 2012

Fiscal Year (FY) 2011 Objectives

- Demonstrate the durability and economic value of GenSys Blue.
- Verify its technology and commercial readiness for the marketplace.

Relevance to American Recovery and Reinvestment Act of 2009 and DOE Fuel Cell Technologies Goals

- The project deploys GenSys Blue, natural-gas fueled, micro-combined heat and power (µCHP) fuel cell units that provide economic savings and environmental benefits for residential and light commercial users.
- The project maintains five U.S., high-tech jobs in New York State and provides work for U.S. suppliers and field service contractors.

Technical Barriers

- **Durability**: Push system durability to commercially viable levels. Critical subsystems and components include stack, burner, reformer, pumps, air delivery module, and controls/software.
- **Cost**: Drive cost down through design simplification, low-cost manufacturing and supply chain.
- **Performance**: Improve system performance and efficiency so the device's value is observed by the customer.

FY 2011 Accomplishments

- Home site assessments were performed in California.
- Three systems shipped to UCI and infrastructure installed at UCI for site preparation.
- Stack life in Latham systems went from an average of 1,500 hours to 3,800 hours.

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Introduction

The high-temperature proton exchange membrane (PEM) fuel cell system is the culmination of a nine-year technology development effort that has produced numerous technical innovations. Plug Power began exploring the application and feasibility of high-temperature PEM technology in 1999 with the creation of an "Alpha" system to demonstrate technical feasibility. It was quickly evident that the high-quality heat produced and the resulting system simplification would make this a preferred technology for µCHP applications–one that held the promise of a commercial, grid-connected, stationary fuel cell product that provided a cost benefit to the end user. Indeed, high-temperature PEM technology offers a unique value proposition over low-temperature PEM systems in applications where heat utilization is required. In a low-temperature system, the quality of the heat supplied may be insufficient to meet consumer needs and comfort requirements, so peak heaters or supplemental boilers may be required. The higher operating temperature of the polybenzimidazole (PBI) membrane technology allows the fuel cell to produce heat for applications that demand higher temperatures required to obtain desirable heat transfer rates without additional equipment.

GenSys Blue is a pre-commercial, 5 kW, natural gas-fueled product that is technically ready to be demonstrated in real-world residential and light commercial installations. The key risks for this technology lie in supply chain readiness and stack material supply. Further refinements in the areas of PBI technology, stacks, advanced controls, and fuel reforming will be made as Plug Power continues to understand technology development needs and product development requirements for this fuel cell system.

Approach

Plug Power is executing a demonstration project that will test multiple units of its high-temperature PEM fuel cell system in residential and light commercial µCHP applications in New York and California. The specific objective of the proposed demonstration project is to understand the durability of GenSys Blue, and thereby verify its path to technology and commercial readiness for the marketplace. In the proposed demonstration project, Plug Power, in partnership with the National Fuel Cell Research Center (NFCRC) at UCI, and Sempra, will execute two major tasks:

- **Task 1**: Internal durability/reliability fleet testing. Six GenSys Blue units will be built and will undergo an internal test regimen consisting of typical residential load profiles to estimate failure rates.
- **Task 2**: External customer testing. Four GenSys Blue units will be installed and tested in real-world residential and light commercial end-user locations in California. (Note: this task was to originally install six systems, but after discussions with DOE was reduced to four)

Results

Plug Power's employees are supporting this effort maintaining an internal and external reliability fleet of GenSys Blue natural gas power systems. Researchers at the NFCRC at UCI are also providing resources to test and understand this system. Commercial suppliers are delivering stack, reformer and balance-of-plant components.

The NFCRC at UCI continued its dynamic modeling efforts of the GenSys Blue system this year. The team has had very good success in modeling the individual subsystems and reactors. Modeling the complete system, however, has proven to be a very difficult task due to the numerical stiffness of the problem. These numerical difficulties arise because this system contains many thermal, energy, and material interconnections. Those interconnections cause the numerical problem to become large and its solution to become slow and unwieldy. The team is exploring methods to help speed up a solution.

Sempra Energy and members of the Plug Power team have begun to finalize the list of sites for the California fleet and have begun preliminary planning and design. The sites are evaluated based on ease of installation, match between customer load profile and system capability, ability to service a given customer site, flexibility of customer in the case of system outage, and anticipated value to the customer.

The team continued long-term reliability testing on the internal fleet installed in Plug Power labs (Figure 1). Table 1 shows that since commissioning in January 2010 the fleet has logged over 30,000 hours of stack operation producing over 50 MWhrs of electricity and 417 MWhrs of heat; averaging over 30% electrical efficiency and over 85% thermal efficiency. During this time the overall, uncorrected, CHP product availability of the fleet was 73%. This compares to 85% from last quarter and is the result of non-operating systems due to the discontinuity in stack material supply. The corrected CHP availability remains at approximately 91%.

In addition, three systems were installed in the NFCRC at UCI. A significant amount of infrastructure work was required to prepare the installation. The installation of heat rejection systems, wiring, piping, and exhaust ducts was completed recently. Plug Power completed two stacks in May 2011 and installed them in the systems in June 2011. The three units at UCI are now running; two systems are in CHP mode and one system is in heat-only operation until a stack is available for installation.

In the past year, the team has seen improvements in stack life. Plug Power has implemented some key advances in stack materials and assembly to more than double stack life. Stack life went from an average of 1,500 hours to 3,800 hours. One stack sample ran in system operation

FIGURE 1. Reliability Testing Fleet Plug Power (left) and UCI (right)

TABLE 1. GenSys Blue Reliability Fleet Statistics

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System S/N	Commissioned Date	System Runtime (Hours)	Current Stack Runtime	Burner Runtime	Electrical kWh	Thermal kWh	Startup Reliability	CHP Operational A(t)
EpsilonPlus8	1/8/2010 14:50	7823	6058	6665	15247	71909	0.67	0.97
EpsilonPlus9	1/11/2010 15:14	4381	3802	5701	7349	60768	0.72	0.51
EpsilonPlus10	4/9/2010 8:55	1777	1777	4744	2520	60265	0.83	0.74
Foxtrot2	1/8/2010 14:59	7325	5256	6251	12769	90359	0.68	0.76
Foxtrot3	3/2/2010 10:47	5011	3098	6517	6679	74977	0.60	0.74
Foxtrot4	6/11/2010 14:45	3212	3212	5851	5948	59111	0.68	0.67
Totals	-	29530	23203	35729	50511	417389	-	-
Average	-	4922	3867	5955	8419	69565	0.70	0.73

for an excess of 6,000 hours. These improvements have been attributed to plate and membrane electrode assembly advances.

Figure 2 shows the breakdown in failure types within the Latham, NY fleet. Although stack life receives a lot of attention because of the cost, we have seen a higher frequency of nuisance failures in the thermal management module (TMM), air delivery module (ADM), and controls module (CM). These reliability issues are correctable and less costly than stack replacement but still need to be addressed in order to move toward commercial readiness.

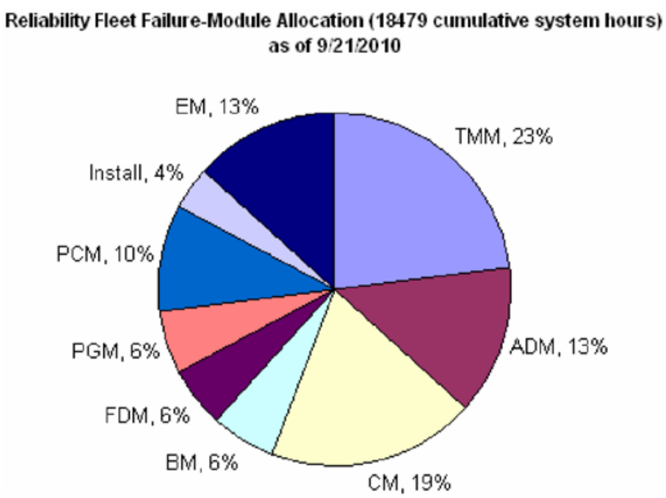

FIGURE 2. Fleet Failure Mode Allocation

Conclusions and Future Directions

The internal reliability fleet has continued to generate data during this past year. The California systems are just coming online and will help us understand the California requirements better. Availability of stack materials remains to be a pacing item and we continue to try to improve the external supply chain and internal manufacturing methods.

Continued progress will help us achieve the following milestones:

- Completion of the full system model by NFCRC.
- Ship and install remaining systems in California.
- Maintain the reliability fleet, capturing requirements from the California market.
- 2nd Go/No-Go decision.
- Perform economic analysis.