V.F.3 Residential Fuel Cell Demonstration by the Delaware County Electric Cooperative, Inc.*

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Subcontractors:
Plug Power, Inc., Latham, NY
Gaia Power Technologies, New York, NY
Energy Now!, Albany, NY
NRECA Cooperative Research Network, Arlington, VA
State University of New York (SUNY) at Delhi
Sandia National Laboratory, Albuquerque, NM
EnerNex, Knoxville, TN

Start Date: October 1, 2004
Projected End Date: January 31, 2007

*Congressionally directed project

Objectives

- Demonstrate viability of grid-independent home
  - typical upstate NY residence.
  - total electrical energy needs provided by fuel cell
  - intelligently managed energy storage
  - in-home load control
  - increased efficiency through thermal recovery
- Validate objectives of propane fuel cells for edge-of-grid residences via a field trial demonstration.
  - measure and report technical performance
  - provide raw cost data and economic viability analysis
  - document maintenance and operations enhancements specific to residential fuel cells
  - share safety related vulnerabilities analysis and lessons learned
  - promote education of state and local consumers

Technical Barriers

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

(I) Hydrogen and Electricity Coproduction

Technical Targets

This demonstration and validation project does not develop new component technologies, and therefore does not have technology targets. Instead, this project will validate technical targets developed within the other subprograms when integrated into a complex system and review the future requirements for integrated systems.

Accomplishments

- Discovered and characterized propane fuel cell start-up problems (stack failures) caused by propane tank de-watering additives.
- Provided real-time and historical system monitoring to the public at http://www.storagemonitoring.com/nyserda-doe/.
- Integrated fuel cell, energy storage, and load management functions into single controller.
- Captured power quality data characterizing flicker problems associated with relatively high impedance distributed generation sources such as fuel cells.
- Operated fuel cell and energy storage systems for 12-month period.
- Hosted regional and community fuel cell education events including a regional press event and a housing tour.
- Co-hosted a 1-day seminar on fuel cells and energy storage for educators and energy professionals.
- Conducted on-site emissions testing of the fuel cell start-up process and steady state operations.
- Decommissioned the fuel cell in June of 2006.

Introduction

DCEC will validate objectives of propane-fueled hydrogen fuel cells for edge-of-grid residences via a field trial demonstration to understand the technical and economic viability of fuel cell alternatives to new line construction. Specifically, they will measure and report technical performance, provide raw cost data and economic viability analysis, document maintenance and operations concept enhancements specific to residential fuel cells, share safety related vulnerability analysis and lessons learned, and promote education of state and local consumers.

Approach

DCEC will engage technology experts in fuel cell and energy storage technologies from Plug Power and Gaia Power Technologies, data collection from Enernex Inc. and Sandia National Laboratories, fuel supply from Mirabito Fuel Group and the Propane Education and Research Council, education and outreach from SUNY Delhi, and technology transfer from Energy Now and the Cooperative Research Network. Co-funding from the NYSERDA/DOE Energy Storage Initiative, the NYSERDA Distributed Generation Program, and the Propane Education and Research Council will leverage and amplify the contribution made by the Department of Energy.

Results

The 12-month fuel cell demonstration resulted in several preliminary findings that will benefit future stationary propane fuel cells. Those findings include the following:

- Characterization of common infant stack failures in propane fuel cells.
- Characterization of electrical flicker issues experienced by the residents of the demonstration home.
- Discovery of inadequacy of the thermal recovery control logic in the Plug Power 5 kW propane fuel cell.
- Emissions tests results.

Each of these technical results will be presented in more detail as follows.

The Plug Power 5 kW propane fuel cell experienced a stack failure soon after commissioning. Conversations with Plug Power staff revealed that infant stack failure has been a consistent problem among their installed base of propane fuel cells. DCEC conducted further research with propane vendor Mirabito Fuel Group, the Propane Education and Research Council, and absorbent material provider Engelhard. DCEC discovered that approximately 2 gallons of methanol was added to the propane tank as a de-watering agent upon installation of the tank. Methanol's high degree of polarity enables its preferential absorption onto zeolite and alumina materials designed to prevent sulfur breakthrough into the fuel cell. Di-methyl sulfide breakthrough then occurs and stack poisoning results. This result has been accepted for publication in the proceedings of the 2006 LP Gas Global Technology Conference.

Electrical flicker was frequently observed in the demonstration residence, which was uncomfortable for the host family. Flicker was caused by step functions in current draw through the inverters in combination with a high impedance power source (fuel cell). Some current draws were caused by load while others were caused by inverter state changes. Flicker is observable by the human eye in many cases and it is also measurable with power quality monitoring equipment utilized by this demonstration project. Figure 1 shows the recorded short term flicker values under three different scenarios: power being fed by the utility grid, during manual switching operations, and power being fed from the fuel cell in combination with energy storage. Note that the flicker value (measured per IEEE 1159) is consistently below 0.8 per unit when grid connected. However, the short term flicker value is frequently above 1.0 when connected to the fuel cell and energy storage system. Flicker becomes noticeable to 50% of the human population at a value of 1.0 per unit, so the flicker values in the demonstration home were at unacceptable levels. The project team worked on various fuel cell-based and inverter-based solutions to the flicker problem. No fuel cell-based or inverter-based solution with acceptable costs could resolve the flicker problem.

Recovered waste heat from the fuel cell was used to pre-heat potable hot water as well as heat living space with baseboard hot water radiators. The combined heat draw of the potable hot water and the baseboard radiators would sometimes attempt to draw more heat than the fuel cell was producing. As a result, it was discovered that the fuel cell's control algorithm did not prevent excessive heat draw from the fuel cell. Therefore, the thermal recovery loop over cooled the fuel cell and

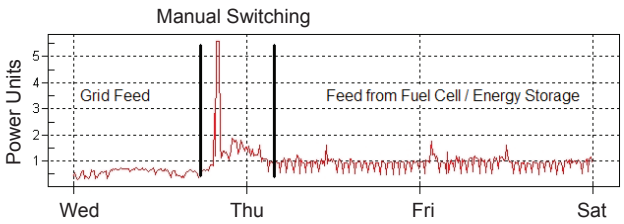

FIGURE 1. Short Term Flicker Measurements

caused unscheduled shut-downs of the system. This is a design consideration for future models of stationary fuel cells.

Emissions testing was conducted in June of 2006 on the Plug Power 5 kW propane fuel cell on-site at the demonstration home. Figure 2 shows the portable emissions lab setup with a sampling tube extending from the fuel cell. The emissions tests covered a time period from a cold-start condition to steady-state operation of the unit. The results indicate higher than expected levels of total organic compounds in the emissions stream. Further analysis of the recorded emissions data will be performed and reported prior to the end of this project.

FIGURE 2. Portable Emissions Lab Setup

Conclusions and Future Directions

Preliminary analysis of the 5 kW fuel cell after the 12-month demonstration period suggests that if properly installed and managed in conjunction with energy storage, the Plug Power fuel cell stack technology is fairly robust and capable of meeting the electrical energy demands placed on it by the demonstration project. The challenges for this demonstration project related to meeting the instantaneous power demands of a load including large swings in demand. More detailed analysis of the demonstration project is scheduled to be conducted between now and January 2007 and will focus on the gaps between the needs of the residential fuel cell application and the system design and performance of the Plug Power 5 kW propane fuel cell in conjunction with Gaia Power Technology's energy storage device.

DCEC will conclude the demonstration of the energy storage portion of the project in December 2006. Data analysis will be conducted prior to January 2007 including summarizing efficiency and performance metrics, durability, operations and maintenance hours, and costs.

FY 2006 Publications/Presentations

1. A presentation regarding the overall project status was given at the DOE Annual Merit Review Meeting (May 2006).

2. M. Hilson Schneider, I. Olsen, Residential Energy Storage and Propane Fuel Cell Demonstration Project by the Delaware County Electric Cooperative, Inc., Proceedings of the Electrical Energy Storage Applications and Technologies Conference, October 2005, California.

3. M. Hilson Schneider, Propane Fuel Cell and Energy Storage Demonstration by the Delaware County Electric Cooperative, Inc., Abstract accepted for the 2006 LP Gas Global Technology Conference, Chicago, Illinois, October 2006.

4. August 2006 – presentations by project partners to large group of public, elected officials, and members of the press at the project press event.

5. Presentations to six local school districts.

6. September 2005 – presentation by M. Hilson Schneider to 400 local members of the community at the DCEC annual meeting.

7. May 2006 – One day seminar presented at SUNY Delhi in conjunction with Lansing Community College of Lansing, MI.