Results of a Residential Proton Exchange Membrane (PEM) Fuel Cell Demonstration at a Military Facility in New York

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ABSTRACT

Residential proton exchange membrane (PEM) fuel cells are in the precommercial stages of development, and limited field testing and demonstrations have been performed to date. This paper provides an overview of the Department of Defense (DOD) Residential PEM Fuel Cell Demonstration Program, as well as an in-depth case study of the ten PEM fuel cells installed at a military facility in New York as part of this program. The installation, operation, performance, and benefits of these units are presented in this paper, along with lessons learned from the demonstration.

INTRODUCTION

Distributed generation technology and devices have received increased attention, due in part to the events in California that led to rolling blackouts in January of 2001, as well as the events of September 11, 2001, which emphasized energy security where critical power assets were at stake. Fuel cells, as a subset of distributed generation devices, have also received increased attention and publicity. The most recent example of increased publicity was the January 2003 Presidential State of the Union Address, where President Bush announced a $1.2 billion hydrogen fuel initiative to reverse America's growing dependence on foreign oil by developing the technology for commercially viable hydrogen-powered fuel cells to power cars, trucks, homes, and businesses with no pollution or greenhouse gases (Bush 2003).

Fuel cells are electrochemical devices, converting a fuel (such as hydrogen) and an oxidant (such as oxygen) into direct current (DC) electricity, heat, and water. The electrochemical nature of fuel cells gives them advantages over conventional generation sources, such as high electrical efficiencies and virtually no emissions. When a hydrocarbon such as natural gas or propane is used as the input fuel, the fuel must be reformed to liberate the hydrogen. This reforming process does produce some particulate pollutants, such as oxides of nitrogen and sulfur (NO_x and SO_x) and carbon dioxide (CO_2). However, the levels of NO_x and SO_x are almost unmeasurable, and the levels of CO_2 are approximately half the levels of a comparable fossil fuel-burning electrical generator. The latter is because the fuel cell is approximately twice as efficient at generating electricity as a fossil fuel-burning device. With regard to power output, for facility applications the DC output of a fuel cell is typically converted to alternating current (AC) by means of an invertor. The waste heat of a fuel cell can sometimes be used in cogeneration applications, which offsets existing heating requirements and correspondingly increases the overall (electrical plus thermal) efficiency of the fuel cell system.

The U.S. Department of Defense (DOD) has invested its own resources to develop and demonstrate fuel cell technology for many years. Warfighter applications of fuel cells, such as for ships, aircraft support, field base camps, heavy trucks, and soldier power requirements, are of particular interest to the DOD. However, the DOD also maintains a large inventory of fixed facilities at its bases, which include buildings of all sizes and types, including office buildings, hospitals, industrial facilities, barracks buildings, and gymnasiums. All of these facilities can benefit from distributed generation, and, in particular, fuel cells, to augment their power, heat, reliability, and security requirements in an environmentally friendly fashion.

Residential PEM fuel cells are in the precommercial stages of development, with limited field demonstrations and

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testing being performed to date. Beginning in fiscal year 2001 (FY01), Congress appropriated funding to demonstrate domestically produced residential PEM fuel cells at military facilities (HR 2000). The U.S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC/CERL), in Champaign IL, was assigned to manage and implement this activity; thus, the DOD Residential PEM Demonstration Program was begun. Subsequent increments of funding in FY02 and FY03 have effectively extended this program, where additional fuel cells are being—and will be—placed at various military facilities.

In this paper, the main focus is a case study of the installation of ten PEM fuel cells at a military facility in New York, conducted under the FY01 Program. This paper addresses the following:

1. A description of the program and its requirements.
2. A description of the military facility, along with a description of the three sites within the base where the fuel cells are located.
3. The specifications of the PEM fuel cells.
4. Highlights and issues from the installation, operation, performance, and benefits of these units.
5. The lessons learned and conclusions.

THE DOD RESIDENTIAL PEM FUEL CELL PROGRAM

As stated earlier, Congress appropriated funding in FY01, FY02, and FY03 to demonstrate domestically produced residential PEM fuel cells at military facilities. The primary objectives for this demonstration program include:

- Assessment of fuel cells in supporting sustainable military installations.
- Increasing the DOD's ability to more efficiently construct, operate, and maintain its installations.
- Assessing the role of PEM fuel cells in supporting the DOD's training, readiness, mobilization, and sustainability missions.
- Providing a technology demonstration site for a military base market.
- Providing operational testing and validation of product to assess installation, grid interconnection, operation of systems in all seasonal conditions, and integration of units into an existing military base environment.
- Stimulating growth in the distributed generation/fuel cell industry.

For this program, ERDC/CERL researchers developed and advertised a broad agency announcement (BAA), which outlined a core set of requirements for proposals. The core set of requirements is presented below.

- All PEM fuel cells shall be substantially produced in the U.S.
- The units will be installed at U.S. military or related facilities.
- The fuel cell contract awardees are responsible for all siting and installation requirements.
- The fuel cells will provide one year of fuel cell power with a minimum 90% unit availability.
- All units will have a comprehensive maintenance contract for a minimum demonstration period of one year.
- Data performance monitoring will be conducted for each PEM unit.
- Removal of the fuel cell(s) and site restoration will be included in the contract price.
- Location of the PEM fuel cell(s) will be in a specified U.S. geographic region.

Beyond the core set of requirements, bidders had the flexibility to propose the number of units, the manufacturer and, subsequently, the specific size and fuel input of the units, and the electrical and/or thermal application of the units, among other attributes. From the FY01 Program BAA solicitation, 12 preproposals were received, requesting a total of approximately $10.6M in funding. After a review period and request and evaluation of full proposals, six contracts were awarded for a total of approximately $3M in funding, representing 21 fuel cells at nine military installations. From the FY02 Program solicitation, 20 preproposals were received, requesting a total of approximately $15.8M in funding. As of March of 2003, five contracts have been awarded, and some are pending due to a recent acqusition of one fuel cell manufacturer by another. For the FY03 Program, the BAA has been issued, and preproposals were due by April 1, 2003. Contract awards are expected to be made between August and December of 2003. A summary of the FY01 Program awards is presented in Table 1.

CASE STUDY

The host military facility is located near Albany, New York. It is part of the U.S. Army Industrial Operations Command, where it is the oldest continually active arsenal in the U.S. Its primary mission is the manufacture of large caliber cannons. Electricity to the military facility is provided by a local electric utility company, and natural gas is purchased through an energy supplier and is based on a negotiated rate.

On October 10, 2001, a New York-based manufacturer of residential PEM fuel cells was awarded a contract to install ten units at three sites within the military facility. These fuel cell systems were rated for a nominal 5 kW power output, with output setpoints at 2.5 kW, 4 kW, and 5 kW. The units were operated in electric-only, grid-parallel mode, using natural gas as fuel. It should be noted that these particular fuel cell models did not have thermal recovery (cogeneration) capabilities. The product specifications for the units are listed in Table 2.

The three base sites chosen for this project include Quarters 19, Building 115, and Building 110. Quarters 19 is a historic building that has been converted into housing that accommodates four separate residences. Four PEMFCs have been placed on this site—one unit for each residence. Building

Table 1. FY01 DOD Residential PEM Demonstration Program Site Summary

Site Name	Building Application	Input Fuel	Size (kW)	No. Units	Cogen. Y/N
Sierra Army Depot	Barracks	Propane	4.5	1	Yes
Brooks AFB	Base housing	Natural gas	5	3	No
MCB Kaneohe Bay	TBD	Propane	TBD	1	TBD
Ft. Bragg	Office building	Natural gas	5	1	No
Ft. Jackson	Officer's quarters	Natural gas	5	1	Yes
Barksdale AFB	Base housing	Natural gas	5	1	No
Patuxent River NAS	Office building	Propane	4.5	1	Yes
Patuxent River NAS	Officer's quarters	Natural gas	4.5	1	Yes
Geiger Field	Maintenance facility	Hydrogen	3	1	No
Watervliet Arsenal	Research facility	Natural gas	5	3	No
Watervliet Arsenal	Manufacturing facility	Natural gas	5	3	No
Watervliet Arsenal	Officer's quarters	Natural gas	5	4	No

115 is a laboratory facility. Three units were placed at this site to support a destructive testing laboratory that is located within the building. The final site was Building 110, which is a heavy machining facility. Three units were placed here to support a telecommunications room. Figures 1 to 3 are photos of the installed units at Quarters 19, Building 115, and Building 110, respectively.

Installation of the PEM Fuel Cell Units

The ten PEM fuel cell units were installed and commissioned in January 2002. In addition to the configurations, each site had its own characteristics and demands that posed challenges to site preparation and unit installation. These challenges are discussed in the following sections (Doud et al. 2002).

Potable Water Requirements. The systems installed at the military facility required a supply of potable water. The water is purified in a deionization (DI) process. Potable water provided by the local municipality presented two challenges.

1. Water quality was tested at 11-12 grains of hardness. This level of hardness would require changing DI filters twice a month. A design modification was made where in-line scale-inhibiting cartridges were installed before the DI filters. These cartridges are expected to extend the life of the DI filters by six months. As a comparison, the manufacturer's experience shows these filters to last one year in normal residential applications.
2. The military facility has six connection points to the public water supply where the New York State Board of Health requires backflow preventors. In addition, the military facility requires a backflow preventor at each building and for each process utilizing water with the possibility of contamination. Each installed backflow preventor reduces static pressure of the water supply by 4 to 5 psi. Water pressure levels dropped from a street pressure of 58 psi to 32 psi measured at one installation site. Normal operating conditions require a minimum static pressure of 40 psi to completely process potable water into DI water. Residential applications typically have 60 psi. Failure to produce sufficiently deionized water could ultimately short the fuel cell stack. To rectify the low water pressure conditions, a booster pump similar to that found on residential wells was installed. The low water pressure problem was solved but resulted in unforeseen installation costs.

Table 2. Product Specifications of PEM Fuel Cells Installed at the Military Facility

Unit Size	Base unit with integral skid: 84.5 in. (214.6 cm) L × 32 in. (81.3 cm) W × 68 in. (172.7 cm) H (excludes 22 in. [55.9 cm] exhaust stack)
Installation Location	Outdoor
Electrical Configuration	Grid Parallel
Power Output/Setpoints	2.5 kW, 4 kW, and 5 kW
Data Collection and Monitoring	Remote via phone line
Output Voltage	120/240 VAC @ 60Hz
Certification	Integrated system: CSA Certified Inverter: UL Listed
Power Quality	IEEE 519 or better
Emissions (steady-state)	NO_x < 0.3 PPM SO_x < 0.3 PPM CO < 5 PPM
Standard Operating Conditions	Temperature: 0°F-104°F (–17.8°C-40°C) Elevation: up to 6,000 ft (1828 m) Noise: < 70 dB at 1 m