V.F.1 Back-Up/Peak-Shaving Fuel Cell Systems

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Objectives

- Develop, build and test three identical fuel cell backup systems and field test them at three sites including an industry host site (BellSouth).
- Identify technical barriers and objectives.
- Develop a cost-reduced, proton electrolyte membrane (PEM) fuel cell stack tailored to hydrogen fuel use.
- Develop a modular, scalable power conditioning system tailored to market requirements.
- Design a scaled-down, cost-reduced balance-of-plant (BOP).
- Certify the design to Network Equipment Building Standards (NEBS) and Underwriters Laboratories (UL).

Technical Barriers

This project addresses the following technical barriers from the Fuel Cells section (3.4.4.2) of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

(A) Durability
(B) Cost
(C) Performance
(G) Start-up and Shut-down Time and Energy/Transient Operation

Technical Targets

Plug Power Progress Toward Meeting DOE Stationary Application Technical Targets

Characteristic	Units	2004 Target	Status
Efficiency at Rated Power	%LHV	50	51
Cost (2,000 units/year)	$\$/kW_e$	<2,000	2,000
Durability	hours	1,500	1,500
Survivability	°C	-25 +40	-40 +46
Cold Start-up Time	sec	<120	20
Noise	dB(A)	<70	<60

Note: Specific targets not available for back-up application; targets developed from DOE Tables 3.4.5 and 3.4.6

Accomplishments

- Completed the final design of the systems to be delivered to the three industry host sites.
- Completed internal verification of system performance to BellSouth requirements.
- Completed UL, CE (European Certification) and NEBS certification requirements.
- Delivered a system to both BellSouth and Argonne National Lab.

Introduction

Plug Power Inc. (Plug), with its customer team member BellSouth Corporation (BellSouth), is engaged in a program to develop, build and test a commercially viable GenCore™ fuel cell system design; a mass-manufacturable implementation of the 2 to 12 kWe GenCore™ architected platform. The GC platform is an autonomous, direct-hydrogen-fueled, DC power fuel cell architecture providing back-up power for premium power applications and DC battery replacement in battery power applications. Our efforts to develop the GenCore specifically for the telecommunications market are greatly enhanced by our teaming arrangement with BellSouth, a Fortune 100 company serving 46 million customers and employing over 80,000 people in Alabama, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, and Tennessee.

Approach

The design and development of the GenCore is leveraging experience gained from the development, testing, and field engagement of Plug's GC5T, a telecommunications product that is the first design for the platform. GC5T testing was completed in 2004 and this field experience has provided the critical customer requirements for a commercial design in this market.

This program utilized a three phase development approach:

- Phase 1: Technology Assessment – During this phase new technologies are developed and evaluated to determine technology readiness for incorporation into the final design.
- Phase 2: Design Development and Verification – In this phase, the design is developed and extensive testing is performed to ensure that the product meets the customer and certification requirements.
- Phase 3: Field Demonstration - In the final phase of the program, the final design is sited in customer applications so that the systems performance can be evaluated at a customer site.

Results

Phase 1 of the program was completed in 2004. In this phase, ten technology initiatives were evaluated. Based on the results of the technology assessment, five of the ten technology initiatives were selected for incorporation into the final design configuration:

- Power Scalable Stack – The fuel cell stack was redesigned to improve manufacturability, reduce cost and reduce size. This was accomplished through a combination of design initiatives:
  - Cost reduced, next generation membrane electrode assembly (MEA)
  - The number of cells was reduced by ~30% through system optimization
  - Thinner bipolar plate design (~20% thinner)
  - Cast aluminum end hardware

Overall, the cost and size of the fuel cell was reduced by nearly 50% and 30%, respectively.

- H2 Regeneration Options - An advanced exhaust gas recirculation (EGR) design which utilizes a venturi was developed to eliminate the overboard exhaust of hydrogen. Previous designs utilized a periodic purge. This purged hydrogen was exhausted from the system to the environment. By incorporating EGR, the purge was eliminated and the exhaust of hydrogen was reduced to less than 1,000 ppm.
- Power Conditioning Platform - A DC/DC converter platform was developed to accommodate multiple end product voltage ranges. The converter was designed such that 66% of the components in the converter are common across all voltage ranges. Only 3% of the components are unique to each version of the converter. This architecture has reduced cost of the converter through economies of scale due to common components.
- Advanced Electrical Energy Storage – One of the key benefits of a fuel cell system is the ability to eliminate batteries from end-user applications. However, in a back-up power application, some form of stored energy is required to start the system in the event of a power outage. It was determined that UltraCaps were a viable solution due to the quick start-up time of the design (<30 seconds). UltraCaps are electrolytic capacitors capable of energy densities greater the 1 W/g. The charge is stored in the electrolyte rather than on the surface of plates. UltraCaps achieve their high capacitance through large surface area and low separation distances. UltraCaps are considered ideal because they degrade slower than batteries and are more tolerant to a greater ambient temperature range (-40 to 46°C). However, UltraCaps are roughly four times more expensive than batteries.
- Scale System - Another key initiative was to develop a system design that is capable of being mass manufactured. Considerable effort was invested in ensuring that components were designed so that they were easily assembled and serviceable in the field.

In 2005, the main effort associated with the program was the development and verification of the final design based on the technologies selected in Phase 1. This process started with the selection of the BOP components required to support the fuel cell. Once the components were selected, the final system layout was developed.

In order to ensure that the end product was mass manufacturable and serviceable, a multi-step packaging process was employed. First, a Pro-E model was created to develop general packaging concepts. Next, several foam core models were built. This allowed the team to quickly build, modify and evaluate several design concepts. Once a design concept was selected, a "Wood Buck" was created. A Wood Buck is a non-functional prototype consisting of a wooden enclosure and the final design configuration components. The Wood Buck allowed the team to quickly understand the complex interaction between the fuel cell system components. Once these interactions were understood, the final design was developed in Pro-E.

Five functional prototypes were built and tested. These systems were used to verify that the final design met BellSouth's requirements. These units were also used to complete the UL, CE, Federal Communications Commission (FCC) and NEBS certification testing.

The BellSouth requirements were verified by performing a series of tests to ensure that the system can operate across a wide range of environmental conditions. Latitude testing was performed from 0 to 5 kw and between –40 and 46°C. The results of the testing showed that the system is capable of starting and operating across the entire range of power and ambient temperature extremes. The testing also confirmed that the system met the audible noise requirements of less than 60 decibels (dBA).

Nearly 230 individual tests were performed to verify compliance to UL, CE, FCC and NEBS requirements. The system was evaluated to the American National Standards Institute (ANSI) FC-1 standard by UL. FC-1 supersedes ANSI Z21.83 and was specifically developed to address fuel cell system safety requirements.

NEBS is a family of standards developed by the telecommunications industry as a design standard for telecommunications equipment. The final design was evaluated to GR-63, GR-1089 and GR-487. These standards require testing across a wide range of ambient environments and potential hazards. A subset of the testing performed is listed below:

GR-63: Network Equipment Building Systems (NEBS) Requirements for Physical Protection

- Temperature and humidity
- Altitude
- Flammability
- Earthquake
- Vibrations
- Airborne contaminants
- Acoustic noise
- Illumination

GR 1089: Electromagnetic Compatibility (EMC) and Electrical Safety

- System-level electrostatic discharge
- Electromagnetic interference
- Lightning and AC power faults
- Steady-state power induction
- Electrical safety
- Bonding and grounding

GR-487: Generic Requirements for Electronic Equipment Cabinets

- Water and dust intrusion
- Wind driven rain
- Rain intrusion
- Lawn sprinklers
- Weathertightnesss
- Acoustical noise suppression
- Wind resistance
- Impact resistance
- Firearms resistance
- Fire resistance
- Corrosion resistance
- Shock and vibration
- Transportation shock
- Transportation rail
- Transportation vibration
- Installation shock
- Environmentally induced vibration
- Earthquake resistance (Zone 4)

In March, two demonstration systems were shipped. One system was shipped to BellSouth. The other system was shipped to Argonne National Lab. The system that was shipped to BellSouth was installed and commissioned on June 6th. This system will be used by BellSouth to validate that the system meets their requirements. Argonne National Lab will be performing baseline testing on the system that they received. The final demonstration system will be delivered to the Federal Aviation Administration in September for a field demonstration.

Conclusions and Future Directions

- The program has completed all of its objectives except the field demonstrations which have been scheduled.
- Five of ten technology initiatives proved feasible and are incorporated into the final design.
- A cost-reduced, PEM fuel cell stack tailored to hydrogen fuel use in back-up applications was developed.
- A modular, scalable power conditioning system tailored to market requirements was developed.
- A scaled-down, cost-reduced BOP was incorporated into the final design.
- The final design was certified to the Network Equipment Building Standards and FC-1 by Underwriters Laboratories.
- Two of the three field demonstrations are underway (BellSouth, ANL). The third demonstration will be installed in September.

FY 2006 Publications/Presentations

1. W.D. Ernst, Small Scale Distributed Stationary Systems – A Status Report. 9th Grove Conference. Westminster, England, October 2005.

2. Bin Du, Qunhui Guo, Richard Pollard, Daniel Rodriguez, Christopher Smith, and John Elter, "Proton Exchange Membrane Fuel Cells (PEMFCs): Technology Status and Challenges for Commercial Stationary Power Applications". Journal of The Minerals, Metals & Materials Society, Volume 58, Issue 7, July 2006.

3. Daniel Rodriguez, Backup/Peak Shaving Fuel Cells – DOE Annual Merit Review Meeting, Washington, D.C., May 2006.