IV.G.3 Back-up/Peak-Shaving Fuel Cells

John Vogel (Primary Contact), William Ernst, Scott Egbert
Plug Power Inc.
968 Albany-Shaker Road
Latham, NY 12110
Phone: (518) 782-7700 ext. 1937; Fax: (518) 786-1494; E-mail: john_vogel@plugpower.com

DOE Technology Development Manager: Kathi Epping
Phone: (202) 586-7425; Fax: (202) 586-9811; E-mail: Kathi.Epping@ee.doe.gov

Objectives

- Develop, build, and test three identical fuel cell back-up systems and field test them at three sites, including an industry host site
- Identify technical barriers and objectives
- Develop a cost-reduced, polymer 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 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 of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

- Distributed Generation Systems
  - E. Durability
  - G. Power Electronics
  - H. Startup Time
- Fuel Cell Components
  - O. Stack Material and Manufacturing Cost
  - P. Durability
  - R. Thermal and Water Management

Approach

- Design the first product based on a mass-manufacturable platform
- Evaluate the design with team member BellSouth
- Evaluate a variety of stack and BOP initiatives
- Build three identical back-up fuel cell systems
- Test three fuel cell systems in-house, one in the field at a BellSouth site and two at a DOE laboratory

Accomplishments

- Constructed models and integrated test rigs (ITRs) and evaluated technology modules
- Ran critical system and module design verification testing
- Developed a power scalable stack

- Developed a power conditioning platform
- Performed a first iteration of BOP system scaling
- Began initiatives for next-generation stack platform
- Received UL certification and completed NEBS testing on prototype
- Field tested prototype

Future Directions

- Complete selection and feasibility testing for technology initiatives
- Complete module testing and ITR integration of technology initiatives
- Complete system-level testing
- Continue development of next-generation stack platform
- Complete prototype field testing
- Design and build three next-generation systems
- Receive UL certification and complete NEBS testing for these systems
- Demonstrate these systems at BellSouth and DOE laboratories

---

Introduction

The purpose of this project is to advance the state-of-the-art of fuel cell technology with the development of a new generation of commercially viable, stationary, back-up/peak-shaving fuel cell systems.

The GenCore II (GCII) back-up fuel cell system is being designed, developed, and tested by Plug Power and will be the first mass-manufacturable implementation of Plug Power's GenCore platform targeted for battery and small generator replacement applications in the telecommunications, broadband, and uninterruptible power supply (UPS) markets. The GCII will be a standalone, H_2-in–DC-out battery and small generator replacement system.

In designing the GCII specifically for the telecommunications market, Plug Power's efforts are greatly enhanced by teaming with BellSouth Telecommunications, Inc., a leading industry end user.

The final GCII system, to be fielded in 2005, will represent a market-entry, mass-manufacturable, and economically viable design. The technology will incorporate the following:

- A cost-reduced PEM fuel cell stack tailored to hydrogen fuel use
- An advanced electrical energy storage system
- A modular, scalable power conditioning system tailored to market requirements
- A scaled-down, cost-reduced BOP

NEBS, UL, and European Commonwealth certification mark (CE) certifications

Approach

The GCII system is being developed from Plug Power's well-defined, modular and scalable system architecture approach, which allows multiple product families to be developed from a common platform, as well as from its self-contained modules, for a diversity of markets. Each market segment represents significant additional sales volume that results in increased unit production and economies of scale.

Plug Power is currently using this architecture approach and the modules developed from it to develop a variety of fuel cell power system products for use with hydrogen and other fuels. Ultimately, multiple product variations will be certified for back-up power systems and for interconnection with the utility grid throughout North America, Europe, and the rest of the world.

The design and development of the GCII will be based on empirical knowledge gained from the development, testing, and field engagement of Plug Power's GC5T system. The GC5T is the first product implementation of the architected GC platform. GC5T testing is allowing the Plug Power/ BellSouth team to identify field performance and customer acceptance issues early in GCII's requirements definition phase.

The GC5T currently fielded is a 5-kW_e DC product adopted from Plug Power's reformer-based product line. Critical platform modules for the GCII are integrated into the GC5T and are being tested as a system. Data is being collected, and the potential of the GC5T to successfully attain customer and regulatory agency (i.e., NEBS, UL) requirements is being assessed.

Results

Performance models and ITRs have been constructed, and technology module testing is underway. Several modules have completed testing and are integrated into systems for system performance testing. Examples of critical tests run to date and their associated data are contained in Table 1.

Table 1. Critical System Tests and Results

Parameter	Tests	Result
System Duty Cycle (> 50 starts/stops per year)	200 start/stop cycles, continuous start/stop cycles, with dormancy and conditioning cycles, performance testing with stop/start cycling	Passed
Operating Hours (1500 hours life)	2000-hour validation	In Process
Time to Fuel Cell Governing (30 seconds)	0 to 5-kWe-ramp test @25°C 0 to 5 kWe ramp test @ -40°C/25°C/+46°C	Passed
Environmental Siting (-40°C to +46°C +solar with 1.5% de-rate/each 10°C > 25C)	5 kWe output test @ +46°C +solar loading Dormancy to net zero output at -40°C	Passed

The completed power-scalable stack initiatives have provided the product with a stack that has comparable performance to Plug Power's residential reformate stack but reduces the number of required cells by 20%, the weight by almost 50% and the volume by 45%. The following initiatives are technology-ready and are being introduced into the current design:

- Reduced stack footprint and thin plates
- Molded-in gaskets
- Reduced end-hardware size
- Integrated insulators and thermostat in the end hardware
- Reduced-cost, scalable scanner card interface
- Next-generation membrane electrode assembly (MEA)

The completed development of the power conditioning platform allows the product the flexibility to address the variety of voltage settings and grounding schemes required by back-up power markets. This platform provides a significant volume and weight reduction over its predecessor and other advantages:

- 13% system efficiency gain
- Greater than 50% cost reduction
- Feasibility, qualification, and ITR integration testing is complete
- Electromagnetic interference testing is complete and the platform is FCC Class A (certified for industrial use) and Class B (certified for residential use)
- UL certification is complete

For the next-generation stack platform, development efforts are focused on plate thickness reduction and gasket configuration as major cost reduction activities. Water management, as it affects peroxide formation, and reactant distribution are the major thrusts for stack life improvement.

The computational study of plenum configurations is underway using FLUENT software in an effort to improve stack power density and reduce stack weight by "right-sizing" the distribution plenum. Additionally, a study of the impact of stack orientation on performance is underway, development of molded-on gasket technology for cost reduction is in process, and a new flowfield that demonstrates 2X lower turndown ratios at equivalent stoichiometry was completed. Finally, experiments have begun to determine the back-diffusion rate of water in the MEA with the ultimate goal of balancing hydration of the membrane while minimizing flooding.

Figure 1. GC5T Installed at Host's Cell Tower

UL certification and NEBS testing are complete on the GC5T. The system has completed NEBS "Level III" testing to GR 487 "*Generic Requirements for Electrical Equipment Cabinets*", GR 1089 "*Electromagnetic Compatibility and Electrical Safety – General Criteria for Network Telecommunications Equipment*" and GR 63 "*Network Equipment-Building System (NEBS) Requirements: Physical Protection*". The GC5T design is deployed to the field at over five customer locations and has logged over 1000 fleet operational run hours and over 1000 starts/stops to date. Figure 1 shows a GC5T at a customer cell tower providing 48 V DC directly onto the customer's DC bus with 5 kW maximum output, running on industrial-grade hydrogen.

Conclusions

- The GC5T is a design that can robustly demonstrate the technologies and customer requirements needed to develop a mass-manufacturable commercial product.
- Having an industry teammate and end user involved in the development of a telecommunications product is indispensable in developing design requirements.
- The back-up power market requires a variety of voltage outputs and grounding schemes that can be addressed with an appropriately designed power conditioning platform.
- Optimization of plenums, flow fields and manifold geometries can significantly improve system turn-down ratios.
- Field testing at commercial customer sites is a critical step in defining detailed industry and application requirements.
- The GC5T has successfully completed all market-required certification testing.
- The GC platform has been demonstrated to support a variety of applications in accordance with customer requirements.
- Continued stack module and power conditioning module design efforts are expected to further reduce size, weight, and cost.