VII.G.2 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 two sites, including an industry host site (BellSouth)
- 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 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 of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

- A. Durability
- B. Cost
- D. Thermal, Air and Water Management
- G. Power Electronics
- J. Startup Time/Transient Operation

Technical Targets

These technical targets for this project were extracted from Table 3.4.9 of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

Table 1. Plug Power Progress Toward Meeting DOEStationary Application Technical Targets

Characteristic	Units	2004 Target	Status
Efficiency at Rated Power	%LHV	50	51
Cost (2000 units/year)	$/kW$_e$	<2,000	TBD
Durability	hours	1500	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

Introduction

Plug Power Inc. (Plug), with its customer team member BellSouth Corporation (BellSouth), is engaged in a project to develop, build and test a commercially viable GenCore™ fuel cell system as a mass-manufacturable implementation of the 2 to 12 kWe GenCore™ architected platform. The GenCore™ 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 design that is the first design from 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. The final configuration will utilize the results of all successful initiatives in Task 2.0. The development approach is as follows:

- Determine product design requirements using BellSouth functional specifications.
- Design the first product off of a mass-manufacturable platform for telecommunications, broadband and uninterruptible power supply markets.
- Select H2-in-DC-out product for telecommunications markets.
- Evaluate a variety of stack and BOP technology initiatives in order to develop a mass-manufacturable and commercially viable design.
- Use rigorous testing and evaluation methods to minimize new technology risks in Phase I, employing Plug Power's Technology Delivery Process.
- Introduce technology initiatives as hardware modules for integration.
- Bring the hardware to an integrated system through field-testing and certification.
- Perform evaluation of onsite test unit at BellSouth.
- Test and evaluate two units at Argonne National Laboratory (ANL).

Accomplishments

Task 2.1 Dry Cathode Stack Operation

- The purpose of this task was to develop the capability for membrane electrode assembly (MEA), stack and system to operate without cathode humidification and evaluate in extended endurance tests.
- A variety of commercial MEAs were tested under GenCore™ operating conditions with an unhumidified cathode. While there were distinct variations in the performance of the MEAs, the

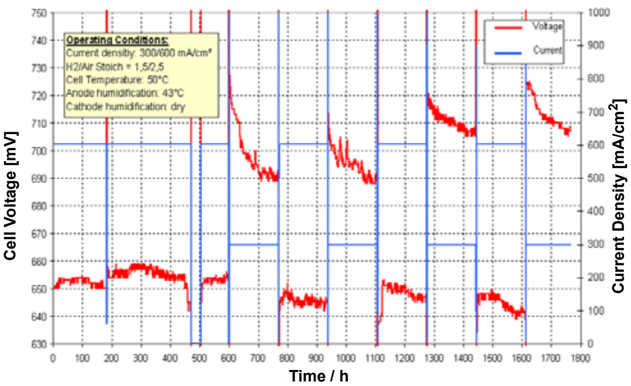

Figure 1. Endurance Test: Commercial MEA, 50 cm^2 GenCore Conditions

general trends were similar; i.e., the membrane dried out but not to the point where the system would fail.

- Testing concluded that for GenCore™ stack life (target: 1500 hrs over 10 years), dry cathode operation is feasible; however, the selected MEAs do not currently meet program cost targets (see Figure 1).
- Upon re-humidification, by operating at high current, the voltage recovers, but the dry-out process is reinitiated in low-current operation.

Task 2.3 Power Scalable Stack

- The final stack design has the following characteristics:
  - – Cost-reduced, next-generation MEA;
  - – Reduction in number of required cells compared to Plug Power's current stack;
  - – Significant reductions in weight and volume;
  - – Significant reductions in direct manufactured cost (DMC);
  - – Increase in heat generation by the stack results in a small increase in stack operating temperature due to fixed radiator size.
- Data shows we can operate the stack with the advanced MEA at increased current densities without compromising performance or reliability (Figure 2).

Task 2.4 H_2 Regeneration Options and Task 2.7 System Water Balance

- The purpose of Task 2.7 was the development of advanced exhaust gas recirculation (EGR) and

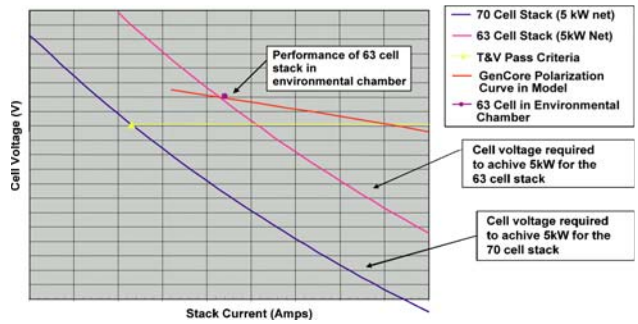

Figure 2. Cell Voltage vs. Current Requirements to Achieve 5 kW Net

electrolyzer options for the next-generation design.

- The advanced EGR option was very successful by maintaining the advantages of EGR:
  - – No purge
  - – Near 100% fuel utilization
  - – Steady performance at very low turndown (zero net power output)
- The advanced EGR configuration demonstrated a 15% more efficient loop while lowering DMC.
- For the electrolyzer option, 22 electrolyzer suppliers were evaluated based on experience, product cost, desire to collaborate, etc.
- The supplier list was down-selected to a single electrolyzer technology (KOH) and vendor.
- While the technology passed the feasibility assessment, the supplier was unable to deliver to purchase order requirements.
- The system water balance initiative was in support of an electrolyzer option. Without an electrolyzer, the GenCore™ system requires no external water source. This initiative was a No-Go.

Task 2.5 Power Conditioning Platform

- The purpose of this task was to develop a power conditioning platform with increased efficiency, lower cost and wider voltage options.
- The final platform design has the following characteristics:
  - – High efficiency (see Figure 3)
  - – Greater than 50% cost reduction over the prototype design through effective power board and DC-DC stage design

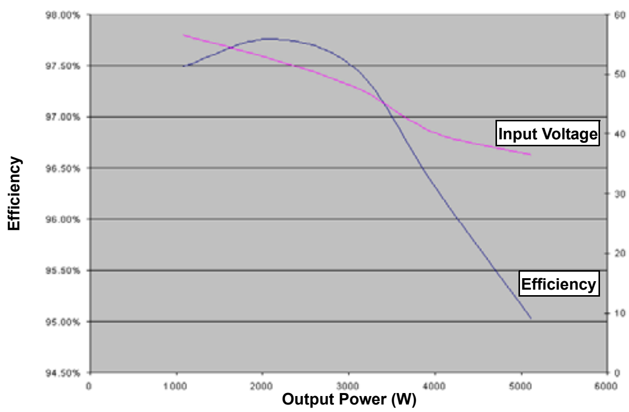

Figure 3. Power Conditioning Efficiency – 120 V System

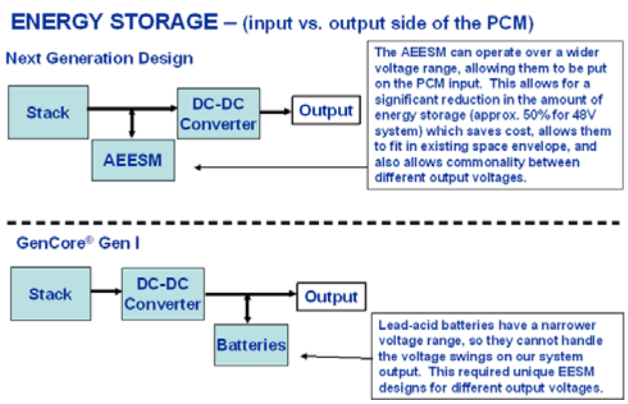

Figure 4. Energy Storage: Input vs. Output of the PCM

- Flexible platform capable of delivering +48V DC, -48V DC, 24V DC and 120V DC

Task 2.6 Advanced Electrical Energy Storage Module (AEESM)

- The purpose of this task was to integrate advanced electrical energy storage into the design of the next-generation system (see Figure 4).
- Energy storage must be maintained on the input side of the power control module. This requires a more robust system characterization and startup reliability.

Task 2.8 Advanced H_2 Storage

- The purpose of this task was to develop a hydrogen storage system (enclosure, delivery, safety, telemetry) using both standard steel bottles and composite cylinders.
- While several composite cylinder commercial products were available, this initiative was abandoned for the following reasons:
  - We were unable to find products that were Department of Transportation (DOT) certified, and the certification process was formidable and beyond the scope of this project.
  - Limited availability of high-pressure (over 3500 PSI) cylinders required either Plug Power or a commercial supplier to stock an inventory of cylinders.
  - Through customer surveys we were unable to demonstrate a business case that justified these investments.
- Customers accept industrial steel cylinders, and this initiative concentrated solely on this concept.
- Plug Power has developed a design (enclosure, delivery, safety, telemetry) that packages industrial steel cylinders to meet the requirements of the customer, UL and NEBS.

Task 2.9 Scale System

- The purpose of this task was to scale the system's BOP to meet reliability, size and cost targets. This was accomplished in two iterations.
- The first was a systems integration and optimization effort which significantly reduced the volume, the weight and the direct materials costs.
- The second is a manufacturability, service and reliability effort designed to create a mass-manufacturable product.

Task 2.10 GenSys Stack and Task 2.2 GenSys Stack Integration

- The purpose of this task was to develop a next-generation, architected stack platform that can be used in GenCore™ to increase life and reliability and to reduce cost.
  - The goal of this stack design is to optimize the following critical characteristics:
  - Manufacturability
    - Low cost
    - Long life
    - Robust operation

  – Serviceability
- Module and first stacks are on target.
- Improvements will continue to end of program.
- Based on the readiness state of the technology, the decision was made to delay cut-in of the GenSys stack into GenCore™ until it is better characterized.

Task 3.3 Perform Field Testing

- The purpose of this task was to field test the GenCore™ prototype system and gather customer requirements.
- Thirteen systems under this project have been installed in installations ranging from lab facilities to telecommunication huts and switchyards connected to DC busses.
- These 13 individual systems have logged over 3000 operational hours and over 2500 starts and stops to date. These systems have well exceeded their design targets. Detailed information on customer training, shipping, installation, commissioning, data collection and operation has been received and continuously drives design and process improvements.
- Plug Power is eager to continue learning and would gladly consider partnering in government or private programs involving the testing and operation of our equipment beyond the demonstrations at BellSouth and ANL.

Future Directions

- The following are our plans for FY 2005 – 1Q 2006.
- Complete technology initiative development through the engineering change process.
- Complete development of the GenSys stack.
- Complete design and design verification testing.
- Complete integrated system testing.
- Build verification test units.
- Conduct field demonstration at BellSouth.
- Certify design to NEBS and UL.
- Demonstrate at two DOE sites.

FY 2005 Publications/Presentations

1. 2005 DOE Hydrogen Program Review