V.D.1 PEM Fuel Cell Powerplant Development and Verification

Eric Strayer
UTC Power (UTCP)
195 Governor's Hwy.
South Windsor, CT 06074
Phone: (860) 727-7238; Fax: (860) 998-9125
E-mail: Eric.Strayer@UTCPower.com

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

DOE Project Officer: David Peterson
Phone: (303) 275-4956; Fax: (303) 275-4788
E-mail: David.Peterson@go.doe.gov

Technical Advisor: Walt Podolski
Phone: (630) 252-7558; Fax: (630) 972-4430
E-mail: podolski@anl.gov

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Objectives

- Evaluate the operation of a 150 kW natural gas-fueled proton exchange membrane (PEM) fuel cell.
- Assess the market and opportunity for utilization of waste heat from a PEM fuel cell.
- Verify the durability and reliability of low-cost PEM fuel cell stack components.
- Design and evaluate an advanced 5 kW PEM system.
- Conduct demonstrations of PEM technology with various fueling scenarios.
- Evaluate the interconnection of the demonstration 5 kW powerplants with the electric grid.

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) Cost

(B) Durability

(C) Performance

Technical Targets

Table 1 highlights the progress made toward the targets specified for fuel cell power plants on reformate in the Fuel Cells section of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan.

TABLE 1. Progress Towards Meeting Technical Targets for Stationary Fuel Cell Power Applications

Characteristic	Units	2011	2008 UTC Power Status
Electrical energy efficiency at rated power	%	40	42% on H_2 On Reformate: TBD
Durability at <10% rated power degradation	hours	40,000	>20,000 hours CSA >3,000 hours in powerplant
Transient response time (for 10% to 90% of rated power)	seconds	1	<1
Survivability (min and max ambient temperature)	ºC ºC	-35 +40	-40 40
Steady state operation (with 2% max air bleed)	ppm	500	

CSA – Cell stack assembly
TBD – To be determined

Additionally, Table 2 is a summary of the progress toward specific targets that are used as success metrics for the project.

Accomplishments

- Completed demonstration of >20,000 hours of cell stack operation.
- Completed the design and fabrication of a prototype advanced system that incorporates significant cost reduction technologies and system simplification for improved reliability, efficiency and performance.
- Achieved >3,000 hours of endurance testing on a baseline 5 kW system, the ultimate goal is 40,000 hours demonstrated in a field application.
- At initial volumes, the cost of the powerplant has been reduced by >40% including transient power and direct current (DC) regulation devices necessary for powerplant operation in a stationary application.
- Demonstrated alternating current (AC) output, parallel operation for "building block" approach for power scalability.

TABLE 2. Progress Towards Meeting Related Technical Targets used as the Basis for Project Success

Parameter	Metric	Demonstration	Result
Rating	5kW, applicability up to 200 kW range power plants	Test (5kW)	Models suggest that water balance will be maintained for rated power at 40C @ 1000meter
Efficiency	>35 %	Test	@5kW net on Pure Hydrogen: Fuel Cell System without power conditioning: 51% With power conditioning: 46% Advanced system projection: 48%
Primary Fuel	Hydrogen from various sources including feasibility for hydrocarbon reformate	Test	2008 Phase III work
Emissions	As good as or better than U.S. requirements	Test	
Operation	Start time < 30 minutes, All U. S. weather conditions	Test	Demonstrated start time is 15 seconds. Cabinet heater required for sub 0 temperatures
Durability	Design goal: ≥15,000 hrs (ultimate application goal ≥40,000 hr) Demonstrated requirement: 1,000hrs, ≥1 year replacement interval	accelerated component and cell stack testing	In non-program demonstrations, 5kW baseline powerplant unit has accumulated 2600hrs with no measurable performance decay.
Mean Time Between Forced Outages (MTBFO)	≥2,000 hours with long term goal of 5,000 hours	Test, statistical analysis	Data to be collected in 2008 endurance testing
Maintainability	Web based remote control, diagnostics	Test	Demonstrated remote monitoring, control with both modem or ethernet capability.
Use of thermal energy	Integration with liquid desiccant	Study	Completed
Grid Interconnectivity	Any US grid with minimal equipment	Demonstration Test, UL 1741 assessment	Phase III AC 120VAC single phase demonstrated Site demonstration partners being sought
High availability & multiple grid connections	Increased availability of power plants & demonstrated grid connections on feeder lines; suitability for backup power application.	Demonstration Test, modeling, and statistical analyses	Baseline 5kW powerplant demonstrated 99.6% availability over 1500hrs

COMPLETED	On Target	At risk	Below target

- Demonstrated an electrolyzer for alternative fuel supply.

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Introduction

This project continues to advance the development and demonstration of the fundamental technologies necessary to enable PEM stationary fuel cell power plants to meet the needs of commercial stationary power applications. This project will continue to demonstrate technology for low-cost, high durability stationary fuel cells using a 5 kW system platform to verify fundamental technologies in a complete system environment. The 5 kW platform is an efficient method to evaluate and build on lessons learned during early 150 kW powerplant demonstration activities. This project continues to accomplish goals to further the development of fuel cell technology toward meeting the demands of stationary applications. Accomplishing these technological achievements will enable commercialization of fuel cells for stationary power applications.

Approach

The focus of this project is to demonstrate technology for low-cost, high durability stationary fuel cells using a 5 kW system platform to verify fundamental technologies in a complete system environment. The approach will focus on three levels of development:

- Fundamentals: Development of fundamental technologies to close technical gaps needed for the commercial viability of fuel cells for stationary applications (i.e., cost, durability, performance and reliability).
- Advanced Power System Development: The advanced 5 kW system will rapidly scale-up technologies developed in the Fundamentals task as well as focus on cost reduction to close technical and commercial gaps.
- Demonstration: The baseline and advanced 5 kW stationary power systems will be tested in lab and field settings to validate durability and performance targets are met as well as develop power system extensions necessary to adapt fuel cells for stationary applications (i.e., AC/DC output and

grid interconnectivity, integration with various H_2 sources, and scalability).

UTCP will evaluate cost-effectiveness and durability of the PEM stationary power plant technologies and system design based on the demonstration results. This approach will enable a robust assessment at the integrated powerplant and sub-system (e.g., cell stack and fuel processor) levels.

Improved component technology will be deployed as lessons learned are accumulated that identify durability and reliability vulnerabilities.

Results

Fundamentals

Alternate low-cost unitized electrode assembly (UEA):

- Internal resistance (IR), open circuit voltage (OCV), fall-off time, and conductivity have exceeded project requirements (Table 3).
- Performance at 1 A/cm^2 is close to minimum criteria.
  - Expected to improve with optimized cathode flow fields.
- Recoverable decay will sustain eight hours of back-up power.

Natural water management (NWM) durability:

- Completed 1,000 load hours and 1,500 start-stops running durability load cycles in NWM mode.
- Overall average decay was ~20 mV over 1007HRS/1520SS.
- End cells had 30% higher decay than the rest of the cells.
- A large portion of the decay is expected to be start-stop decay as the quality of H_2 on the unit was not fully mitigated.
- Low coolant flow mode coolant clean-up and reduction in the number of start-stop cycles helped to recover/sustain performance loss.

TABLE 3. Summary of Alternate UEA Testing Results

Product	IR (mV/100 masc)	mV @ 1000mA/cm^2	OCV (mV)	Conductivity (uS)	Falloff Time (min)
PEM CSA Spec	<15	>600	>898	<1	>1
Alternate UEA, 1000 hours	10.2	531	979	0.87	9.04
Baseline UEA	13	628	945		4.7

Figure 1 summarizes the performance of the NWM system throughout the various stages of the testing.

Advanced System

- Rated power reached after 3 days of testing.
- System met power output, efficiency, and initial water balance test requirements.

Performance was comparable to the baseline system as shown in Figure 2.

Demonstrations

5 kW Baseline Power system endurance testing:

- Phase I testing completed under non-DOE program:
  - Continued endurance hold at 2 kW net power until 2,500 hours.

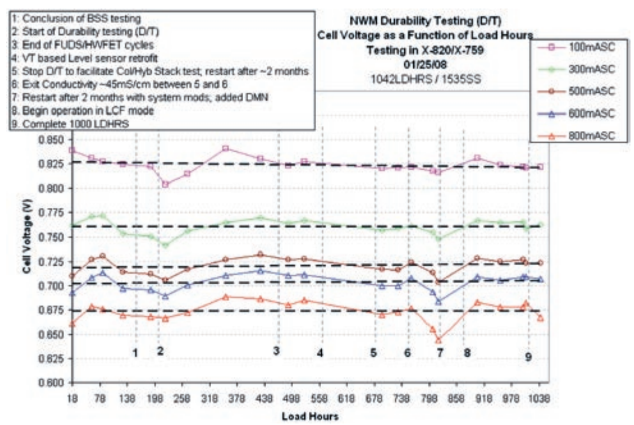

FIGURE 1. Performance and Test History Summary of the NWM System Durability Testing

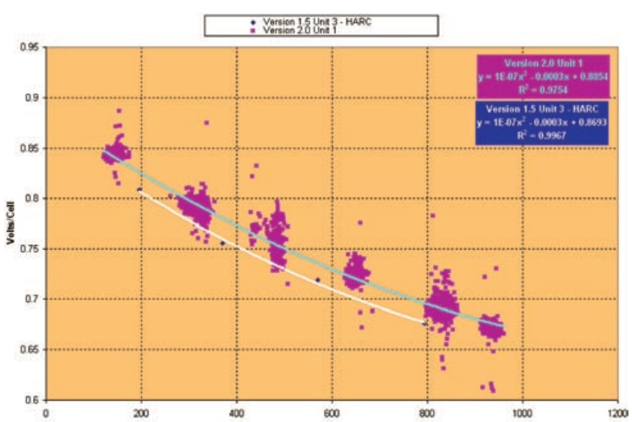

FIGURE 2. Performance Comparison of Advanced and Baseline 5 kW Fuel Cell Power Systems

- At 1,500 hours: average efficiency = 42%, availability = 99.6%.
- Phase II Testing in progress under DOE project:
  - 9,253 kilowatt hours, 3,284 load hours, and 601 starts.

AC demonstration:

- Parallel system assembled with inverters, rectifiers, transfer switch and AC distribution monitor.
- AC output and parallel system operation testing was completed.

Flexible fuel source:

- Electrolyzer
  - Grid independent solution demonstrated.
  - Initial operation to 2,300 PSI without a compressor completed.
  - Phase III to complete 6,000 PSI hydrogen production.
- Reformer
  - Conceptual design initiated, to be completed in Phase III.
  - Fuel cell combined heat and power and reformer system procured and undergoing testing for investigation of optimized cost-effective fuel processor design.

Conclusions and Future Directions

With the accomplishments and progress toward technical goals, this project has made strides to close technical gaps. Continued emphasis on the development and scale-up of technologies to improve durability, cost and performance will be necessary to make a fuel cell that meets all targets for commercial stationary applications:

- Durability: >20,000 hours of CSA endurance will need to be validated through the scale-up and demonstration in stationary fuel cell powerplant operation.
- Cost: At initial volumes, the cost of the powerplant has been reduced by >40% including transient power and DC regulation devices necessary for powerplant operation in a stationary application. Continued focus on low cost technology development and scale-up for field demonstration will be a necessary step for determining commercial viability of the powerplant in stationary applications (i.e., backup power, peak shaving, prime power).
- Performance: performance and efficiencies are improved, however, additional work will be necessary to verify performance and efficiencies on fuel from reformers and alternative fuel sources.