

VI.2 PEM Fuel Cell Powerplant Development and Verification

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 Project End Date: December 31, 2009

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:

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

Technical Targets

Table 1 highlights the progress made toward the targets specified for fuel cell power plants on reformat in the Fuel Cells section of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan. Additionally, Table 2 is a summary of the progress toward specific targets that are used as success metrics for the project.

TABLE 1. Progress Toward Meeting Technical Targets for Stationary Fuel Cell Power Plants Operation

Characteristic	Units	2011	2009 UTC Power Status
Electrical Energy Efficiency @ Rated Power	%	40	45% on H ₂ On Reformat: TBD
Durability @ <10% Rated Power Degradation	hours	40,000	>20,000 hours Cell Stack Assembly ~4,000 hours in power plant
Transient Response Time (for 10% to 90% of rated power)	seconds	1	<1
Survivability (min and max ambient temperature)	°C °C	-35 +40	-40 40

TBD - to be determined

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 technology and system simplification for improved reliability, efficiency and performance.
- Developed 5 kW advanced fuel cell power plant with >20% increase in volumetric power density that achieves parity with similar internal combustion-based power plants.
- Achieved ~4,000 hours of endurance testing on a baseline 5 kW system and 400 hours of testing on the advanced 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 >30% 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 Toward Meeting Stationary Fuel Cell Program Metrics

Parameter	Metric	Demonstration	Result
Rating	5 kW, applicability up to 200 kW range power plants	Test (5 kW)	5 kW powerplant constructed with rated power up to 40°C @ 1,800 meters. Scalability in 5 kW building blocks feasible for AC and DC applications. Design is scalable to larger power applications
Efficiency	>35 %	Test	@ 5 kW net on Pure Hydrogen: Fuel Cell System without power conditioning: 51% Advanced system with power conditioning: 45%
Primary Fuel	Hydrogen from various sources including feasibility for hydrocarbon reformat	Test, Analysis	Study for natural gas, LPG, propane underway.
Emissions	As good as or better than U.S. requirements	Test	Zero emissions. Hydrogen concentration in exhaust is less than 25% LFL under all operating conditions. Not yet analyzed for reformer based system.
Operation	Start time < 30 minutes, All U.S. weather conditions	Test	Demonstrated start time is 15 seconds (Hydrogen based system). Not yet analyzed for reformer based system.
Durability	Design goal: ≥15,000 hrs (ultimate application goal >40,000 hr) Demonstrated requirement: 1,000 hrs, ≥1 year replacement interval	accelerated component and cell stack testing	5 kW baseline powerplant unit has accumulated ~4,000 hrs with <10 μV/hour of non-recoverable performance decay.
Mean Time Between Forced Outages	>2,000 hours with long term goal of 5,000 hours	Test, statistical analysis	Reliability model projects 1,800 hours and testing is ongoing to increase the projection.
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 U.S. grid with minimal equipment	Demonstration Test, UL 1741 assessment	AC 120 VAC single phase demonstrated AC grid connect inverter under development for demonstration in 2009.
High availability and multiple grid connections	Increased availability of power plants and demonstrated grid connections on feeder lines; suitability for backup power	Demonstration Test, modeling, and statistical	Baseline 5 kW powerplant demonstrated 99.6% availability over 1,500 hrs

COMPLETED	On Target	At risk	Below target	LPG - liquefied petroleum gas LFL - Lower flammability limit
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- Demonstrated an electrolyzer as an alternative fuel supply.



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 power plant 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 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 hydrogen sources, and scalability).

UTC Power 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), falloff time, and conductivity have exceeded project requirements.
- Performance at 1,000 mA/cm² is close to minimum criteria:
 - Some air sensitivity at high current densities after 1,000 hours. This will be monitored during endurance testing after installation in a power plant.

Table 3 summarizes the development progress to date for the low-cost UEA.

Advanced System

- System met power output, efficiency, and initial water balance test requirements.
- Endurance testing in progress (>400 load hours @ 5 kW, >100 start-stop cycles (Figures 1 and 2).



FIGURE 1. Advanced 5 kW System Undergoing Endurance Testing

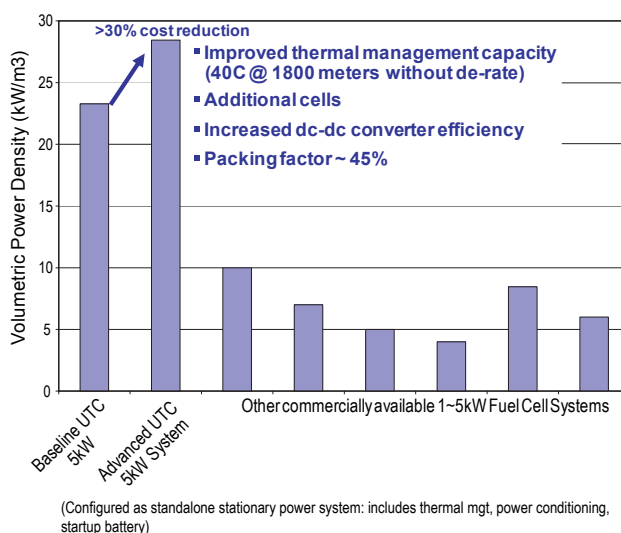


FIGURE 2. Benchmarking Results of UTC Advanced 5 kW System's Power Density

TABLE 3. Summary of Alternate UEA Testing Results

Product	IR (mV/100 mAsc)	mV @ 1,000 mA/cm ²	OCV (mV)	Falloff Time (min)	Recoverable Decay (μV/hr)	Non Recoverable Decay (μV/hr)
5 kW PEM CSA Spec	< 15	600	898	> 1	< 70	< 21
Baseline UEA (30-Cell CSA)	13	628	945	4.7	457	
Alternate UEA-1 30 cell, 500 hrs	10.2	570	979	9.04	226	47
Alternate UEA-2	8	642	982	> 10	239	< 21 (682 Load hours)
33-Cell stack with Alternate UEA-2	12	654	> 970	7.9	616 (1,000 hrs)	29

CSA - cell stack assembly

Demonstrations

UTC 5 kW previously developed baseline power system endurance testing.

Testing completed under non-DOE program:

- Continued endurance hold at 2 kW net power until 2,500 hours.
- At 1,500 hours: Average efficiency = 42%, Availability = 99.6%.

Testing in progress under DOE project:

- ~4,000 load hours, and >450 start-stop cycles.

The advanced 5 kW system is based on the UTC baseline system and incorporates low cost cell stack assembly technology, improved power density, increased operating envelope and higher power conditioning efficiency. Field demos with the advanced system will be conducted with selected key end users and at the UTC Power facility to gain reliability data and field experience.

AC Demonstration:

- Parallel system designed and 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.
 - >1,000 hours runtime was achieved.
 - New membranes installed to enable 3,000 PSI hydrogen production.
- Reformer
 - Conceptual design initiated.
 - Fuel cell combined heat and power and reformer system undergoing testing.

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 cell stack assembly 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 more than 30% 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 power plant in stationary applications. Performance and efficiencies are being improved; however, additional work will be necessary to verify performance and efficiencies on fuel from reformers and alternative fuel sources.

FY 2009 Publications/Presentations

1. 2009 DOE Hydrogen Program Review – Washington, D.C. - May, 2009. Presentation FC#26.