V.J.2 Development of a Low-Cost 3-10 kW Tubular SOFC Power System

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Fiscal Year (FY) 2012 Objectives

The goal of the project is to develop a low-cost 3-10 kW solid oxide fuel cell (SOFC) power generator capable of meeting multiple market applications. This is accomplished by:

- Improving cell power and stability
- Cost reduction of cell manufacturing
- Increase stack and system efficiency
- Prototype testing to meet system efficiency and stability goals
- Integration to remote and micro-combined heat and power (mCHP) platforms to allow short and longer term market penetrations

Technical Barriers

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

(A) Durability
(B) Cost
(C) Performance

Technical Targets

This project is directed toward achieving the stationary generation goals of the DOE fuel cell power systems. This project will work on cost reduction of the desired product while also demonstrating required life and efficiency targets through multi-level testing.

TABLE 1. Progress towards Meeting Technical Targets for Stationary Fuel Cell Power Generators

Characteristic	Units	2011 Goal	2011 Status
Electrical Efficiency	%	40	40
CHP Efficiency	%	80	85
Durability @<10% Rated Power Degradation	hours	40,000	12,000
Start-Up Time	minutes	<30	<20
Transient Response (from 10-90%)	seconds	<3	<10
Cost	$/kWe	$750	$729 (estimate on volume)

FY 2012 Accomplishments

- Improved cell stability and increased current density and therefore increased power per cell.
- Demonstrated acceptable thermal cycle stability for entire systems.
- Reduced the overall parasitic load on the generator by nearly 20% enhancing overall system efficiency.
- Reduced part count per system by 48% in the past year to reduce cost and ease the manufacture of initial commercial systems.

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Introduction

Achieving combined heat and power goals of over 40% net electrical efficiency and over 85% total energy efficiency are goals of the DOE and present administration to reduce our dependence on foreign energy and reduce the emission of greenhouse gases. SOFCs, with their ability to use the present U.S. fuel infrastructure and high grade waste heat are ideal candidates for this challenge. To date, the limitation on making this goal a reality has been the reliability and cost of such systems.

This project is designed to address these limitations and bring this promising technology to the market place. This is being achieved by working on all aspects of the SOFC power generator including: (1) improving cell power and stability, (2) cost reducing cell manufacture, (3) increasing stack and system efficiency, (4) prototype system testing, (5) and integration into a mCHP platform. This phase of the project will make a major drive toward the DOE's goals set forth for 2012 stationary power generators.

Approach

To achieve the project objectives, the approach has been to perfect the individual system pieces followed by optimizing their integration through:

- **Cell Technology:** Improving power and stability of the cell building block.
- **Cell Manufacturing:** Improving processing yield and productivity while decreasing material consumption.
- **Stack Technology:** Refining stack assembly and improve heat removal and integrity while cost reducing individual component costs.
- **System Performance:** Developing simplified controls and balance-of-plant (BOP) components to allow for a reliable, highly efficient unit.

Results

In the past years review, increases in efficiency and current density were demonstrated showing the overall goals of the DOE Hydrogen and Fuel Cells Program could be met. It was stated in last year's summary that further work would be performed into durability and also sub-assembly and overall system cost reduction to allow for the introduction of a commercial product. All of these goals were met in the research performed under this project in 2011.

In the 2011 write-up, it was demonstrated that the current density could be increased from 150 mA/cm^2 to 250 mA/cm^2 for thousands of hours. Figure 1 shows that the current density was further increased from 250 mA/cm^2 to 350 mA/cm^2. During this period, it was shown that the voltage actually slightly increased with the increase in current density. This is most likely due to some sintering of the electrical connections between cells. Cells are now repeatable tested at a minimum of 250 mA/cm^2 and over 350 mA/cm^2. As such, a machine capable of 500 W for remote power now only requires 10 cells where in the past it could require as many as 45 cells.

To demonstrate stability of overall systems, one of Acumentrics' commercial entry machines was tested under thermal cycle conditions. Figure 2 shows the voltage and current density traces of a remote power machine operational on line natural gas and connected to a remote direct current (DC) load. The unit operated autonomously over approximately a two week period and completed over 20 thermal cycles to room temperature. In this period, the unit had a voltage decrease of less than 2% over those cycles. During subsequent steady-state operation, some of this 2% was recovered. Based on these results, it is believed that the thermal cycle stability of the present technology is sufficient

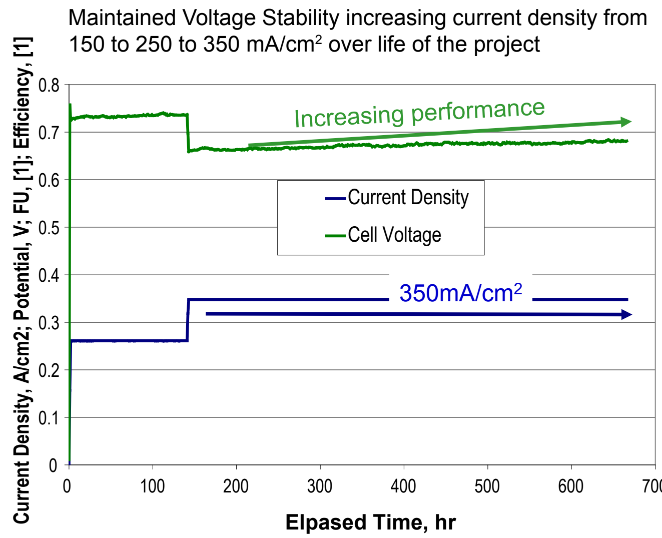


FIGURE 1. Cell Stability at Increased Current Density

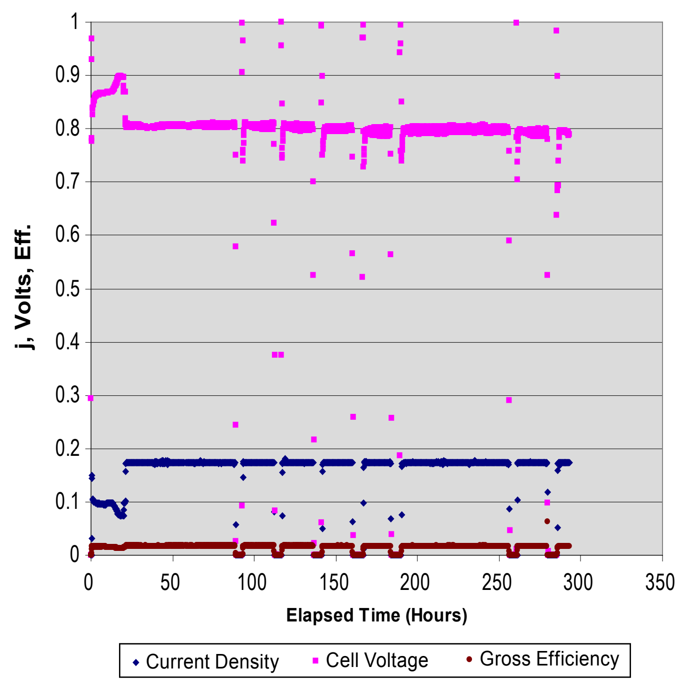


FIGURE 2. Performance Stability during Thermal Cycles

for continuous remote power operations as well as mCHP devices which probably would only cycle one or two times per winter heating season.

In additions to gains in cell power and stability, enhancements were made in reducing the overall parasitic consumption of the unit. Last report period it was noted that with improvements in cell performance and reforming technology that the overall DC efficiency had exceeded 40%, even at power levels at or below 1 kW. To assure that the overall system could also exceed 40%, work was done in

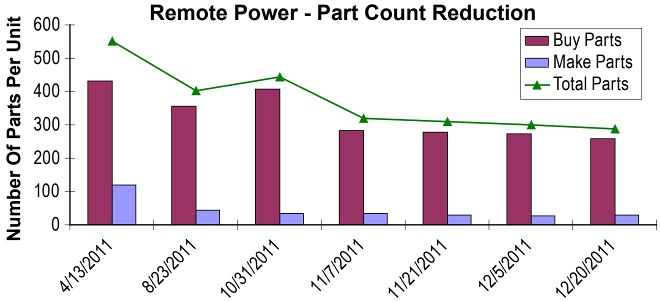


FIGURE 3. BOP Power Consumption Reductions

reducing from two blowers to one blower on partial oxidation machines. Figure 3 shows the comparison of blower power, the largest single parasitic consumer, for both two blower and one blower machines. Over 33% of the overall blower power, and approximately 20% of the overall parasitic consumption, were recovered with this advancement. The total parasitic power is now below 100 W and is capable of supporting machines up to ~3 kW output.

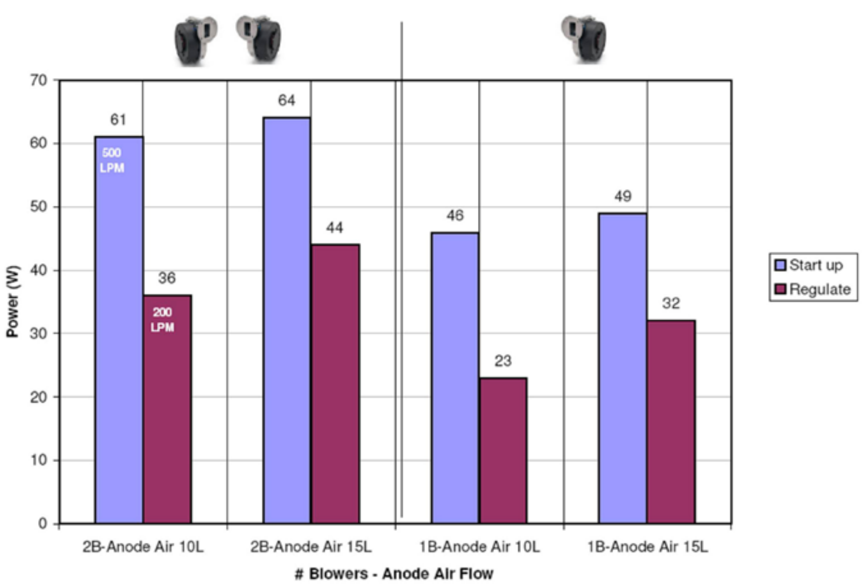
To simplify the overall system, effort has been made into manufacturing scale up with both reductions in labor and materials. For an initial product offering in the remote power market, systems between 500 W and 1,500 W have been designed and tested. These systems are proving to be the platform upon which mCHP systems are being developed. For the remote market, and especially the mCHP market, significant focus is needed in cost reduction. Figure 4 shows the significant part count reduction made for each system during the 2011 period. The year started with each system requiring 551 parts and ended at 287 parts for a reduction of 48%. Likewise, the amount of parts internally manufactured was reduced through effective use of local vendors more suited at mass production of strategic components. Through this focus and emphasis on labor reduction, Acumentrics has developed a system capable of commercial sales in the remote power market. For penetration of the mCHP market, significantly more funding will be required to further enhance performance and durability as well as continue cost reduction.

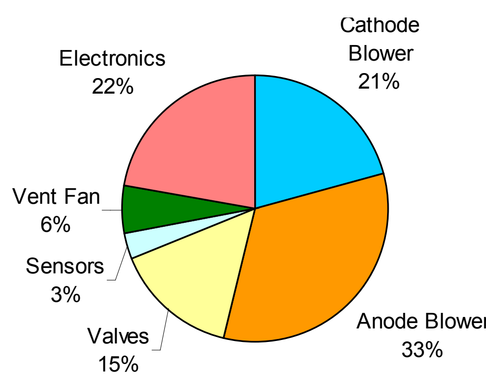
Conclusions and Future Directions

Significant strides have been made in achieving the goals set forth for stationary fuel cell generators under the DOE multi-year plan.

- Improved cell stability and increased current density and therefore increased power per cell.
- Demonstrated acceptable thermal cycle stability for entire systems.
- Reduced the overall parasitic load on the generator by nearly 20% enhancing overall system efficiency.
- Reduced part count per system by 48% in the past year to reduce cost and ease the manufacture of initial commercial systems.

Moving forward, further testing to achieve all of the DOE multi-year goals will be performed as well as cost reduction of the cell and all major sub-systems. Work will continue on market introduction of the technology into remote markets for short term introduction as well as mCHP for longer term market penetration.





	Power (W)
Cathode Blower	17
Anode Blower	27
Valves	12
Sensors	3
Vent Fan	5
Electronics	18
	81

FIGURE 4. Product Part Cost Reductions

FY 2012 Publications/Presentations

1. 2011 Fuel Cell Seminar, "Progress in Acumentrics' Fuel Cell Program", Orlando, FL, October, 2011.

2. 2012 DOE Hydrogen Program Review. Washington, D.C., May 16, 2012.