Development of a Low Cost 3-10kW Tubular SOFC Power System

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Overview

Timeline
- Project Start: 4/1/2008
- Project End: 9/30/2012
- Percent Complete: 95%

Barriers
- Cell Power Density
- Stack Power Density
- Cell Cost Reduction
- System Cost Reduction
- System Efficiency
- Lifetime

Budget
- Project Funding
  - DOE Share=$11,692,737
  - Contractor=$3,897,579
- Funding Received
  - 2011 $0
  - 2012 $537,838
Relevance/Objectives

- Improve Cell Power & Stability
- Cost Reduce Cell Manufacturing
- Increase Stack & System Efficiency
- Prototype Testing to meet system efficiency and stability goals
- Integrate to remote power and mCHP platforms to allow short and longer term market penetrations
Technical Approach

Perfect the individual System pieces followed by optimizing their integration:

- **Cell Technology**: Improve power & stability of the cell building block
- **Cell Manufacturing**: Improve processing yield & productivity while decreasing material consumption
- **Stack Technology**: Refine stack assembly and improve heat removal and integrity while cost reducing components
- **System Performance**: Develop simplified controls and BOP to allow for a reliable, highly efficient unit.
Proposed Future Work - 2011 Annual Meeting

- Assure cell stability
  - Continue testing at 250 to 400mA/cm² current density
  - Further demonstrate stability over thermal cycles through cell & stack testing

- Continue cost reductions on each product platform
  - Continue cell manufacturing automation-maintaining performance
  - Reduce Generator & BOP costs to levels allowable for remote power products – complete “make/buy” decisions on all major sub-assemblies

- Move from field testing of first market products to second market products
  - Continue to build on success of remote power units and accept commercial orders
  - Field demonstrate liquid fueled military units in the 1-3kW range.
Technical Accomplishments & Progress

Maintained Voltage Stability increasing current density from 150 to 250 to 350mA/cm² over life of program

Increasing performance

Current Density: 350mA/cm²
Cell Voltage: 0.7 V
Technical Accomplishments & Progress

Performance Loss <2% over 20 thermal cycles on Full System Testing
Tri-sintering development – Process Step Removal

7.5 Days to process 100 tubes through to electrolyte sinter using standard processing methodology
Technical Accomplishments & Progress

With the development of a tri-sinter for the tube, active anode and electrolyte, a significant time saving will be realized.

5.0 Days to process 100 tubes through to electrolyte sinter using proposed tri-sinter

2.5 Day improvement
Technical Accomplishments & Progress
Pick & Place Robot – Straightness Measurement

- Removes labor from tube straightness and coating thickness QC measurements.
- Enabled QC data to be collected on larger sample sizes without additional labor – set baseline for quality
- Developed load/unload robotics for many future automation projects
- Common part holder utilized
Technical Accomplishments & Progress

Pick & Place Robot – Cathode Spraying

- Fully automated cathode and barrier layer spraying
- Slurry management system implemented – improved coating uniformity
- Elimination of all masking
- Slurry utilization near 100%
- Common part holder utilized
Manufacturing Development Activities

- Established 4 assembly lines leading to final assembly area
- Part count has been reduced from 551 to 287 since April 2011

Remote Power - Part Count Reduction

- Buy Parts
- Make Parts
- Total Parts

Numbers of Parts Per Unit:

- 4/13/2011
- 8/23/2011
- 10/31/2011
- 11/7/2011
- 11/21/2011
- 12/5/2011
- 12/20/2011
Simplified BOP- Parasitic Power Reduction

![Graph showing power distribution by component]

- Cathode Blower: 21%
- Anode Blower: 33%
- Valves: 15%
- Sensors: 3%
- Vent Fan: 6%
- Electronics: 22%

<table>
<thead>
<tr>
<th>Power (W)</th>
<th>Cathode Blower</th>
<th>Anode Blower</th>
<th>Valves</th>
<th>Sensors</th>
<th>Vent Fan</th>
<th>Electronics</th>
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**Total Power (W): 81**
Cost Reduction of Fuel Cell Module

- Simplified metal forming and welding
- Outsourced routine fabrication
- Thermal Insulation cost reduced by 65%, 85% potential
- Recuperator cost reduced by 45%
Product Portfolio

Remote Power

Military Generators

mCHP
Remote Communication Applications

- Powering Communication systems where solar not applicable
- Reciprocating engines not applicable due to low MTBF
- Powers ranging from few 100W to kW’s
Remote DC Power Installations

- Three Units Initially Installed
- Follow on order for 25 units
- Operating with multiple DC outputs
- Longest units in field for 9 months with high 90’s reliability
Long term internal testing at 40-45C (104-113F) has shown no negative impact on life.
Rollup Statistics

- **Alpha Units (11 units)**
  - 72,250 operational hours
  - 36,074kW-hr produced
  - 73.4% availability

- **Beta Units (15 units)**
  - 34,379 operational hours
  - 12,568kW-hr produced
  - 91.2% availability
mCHP – RP-20 Integration

Testing in Italy & Switzerland late 2012/early 2013
1kWe, 20kWt
Certified to European Standards

Standard RP-20 Unit

DC/AC Inverter

Heat Recovery Unit
Proposed Future Work

- Complete RP-20 mCHP integration
- Continue cost reductions on each product platform
  - Continue cell manufacturing automation - maintaining performance
  - Reduce Generator & BOP costs to levels allowable for remote power products – complete “make/buy” decisions on all major sub-assemblies
Summary

- Increased power output and thermal cycle capability of system from cell level
- Significant cost reductions in cell and overall system to allow for market introduction
- Improved reliability of overall system exceeding that available for power generation in the field
- Continue to make steady progress into short, medium, and long term markets for fuel cells.