Fuel Cells Provide Clean, Quiet Off Grid Power for CP and SCADA Applications on Natural Gas Pipelines and Well Casings

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Acumentrics SOFC Corporation
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CLEAN RELIABLE POWER

Why Use a Fuel Cell for Remote Power?

- More Efficient than Incumbent Solutions
  - ~2x Internal Combustion Engine (GenSets)
  - ~10x Thermal Electric Generators (TEGs)
- Low Maintenance
  - Solid state fuel cell construction
  - One year service interval
- Clean & Quiet
  - No combustion
  - Reduced emissions
  - No oil or coolant to chg or spill
- Easy Installation
  - Modular, Scalable, 500w increments
  - Natural Gas or Propane Fueled
  - Minimal theft attraction
  - Remotely controlled and monitored
Why Use a Fuel Cell for Remote Power?

- Higher Efficiency  →  Significant Fuel Savings

High efficiency SOFC generators achieve significant fuel savings vs. incumbent technologies.
Efficiency and Natural Gas Consumption of Fuel Cell Generator in Remote Power Application
Why Use a Fuel Cell for Remote Power?

Higher Efficiency ➔ Significant Natural Gas Savings

<table>
<thead>
<tr>
<th></th>
<th>Thermoelectric Generator (TEG)</th>
<th>Solid Oxide Fuel Cell Generator (SOFC)</th>
<th>Annual Savings per Site Enabled by Using SOFC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fuel</strong></td>
<td>Natural Gas</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>DC Output Power</strong></td>
<td>500 watts</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Energy Output per Year</strong></td>
<td>4380 kWh</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Nominal Net System Efficiency, %</strong></td>
<td>2%</td>
<td>30%</td>
<td></td>
</tr>
<tr>
<td><strong>Fuel Used per Year, cubic ft</strong></td>
<td>747,408</td>
<td>49,827</td>
<td>697,581 Cubic Ft/Year</td>
</tr>
<tr>
<td><strong>Fuel Cost per Year, at $5.00/Thousand Cubic Ft price at Wellhead</strong></td>
<td>$3,737</td>
<td>$249</td>
<td><strong>$3,488</strong> Fuel Savings per Year</td>
</tr>
</tbody>
</table>
Environmental Impact of Switching from a Thermoelectric Generator (TEG) to an SOFC Remote Power Generator

- One 500W Continuous Output System
- Savings of ~700,000 ft³ of Natural Gas per year
- 0.125 lbs of CO₂ created per cubic ft of gas consumed

Green Facts: The average US car emits ~9 or 10 thousand pounds of CO₂ per year

In addition to the CO₂ reductions, an SOFC generator produces no measurable amount of the NOx and SOx compounds that contribute to air pollution

Offsets Carbon Emission of ~10 Cars

Green Bucks!!
Federal/State Tax Credits and Carbon Offsets of up to $3,000
Basics of SOFC Technology

- **Tubular Ceramic Cells**
  - Inherent strength and tolerance to rapid temperature change
  - Low-cost nickel oxide catalyst – **No Platinum or expensive noble metals!**
Fuel Processing - Reforming of Hydrocarbons into Hydrogen & CO

Partial oxidation (dry reformation) of methane:

\[ \text{CH}_4 + \frac{1}{2} \text{O}_2 \iff \text{CO} + 2\text{H}_2 \]

Steam reformation of methane:

\[ \text{CH}_4 + \text{H}_2\text{O} \Rightarrow \text{CO} + 3\text{H}_2 \]

Sulfur is removed from fuel gases using sorbents, which selectively adsorb sulfur containing species.
SOFC System Block Diagram

- Tubular Ceramic Cells
  - Inherent strength and tolerance to rapid temperature change

- High Operating Temperature (800°C)
  - Internal fuel reforming
  - Optional cogeneration

- Standard Manufacturing Process
  - Low CapEx

- Standard Components
  - Standard HVAC balance-of-plant components
  - Leverage 12 years DC/AC conversion experience
Mechanical Configuration of Major System Components

- 1000W Gross DC Output from FC Bundle
- Low profile ~22” height
- Black start Capable
- Internal Data Acquisition & Satellite Communication
- Start-up 20 minutes
- Replaceable stack design
Stack Configuration

- Bundle of 4 x 9 cells
- 36 cells electrically in series
- One common anode fuel distribution plenum
- One common offgas collection plenum
Flexible Design for Multiple Applications

- Configured in up to 10kW power packages
- Compatible with commonly available fuels
  - Natural gas, propane, low sulfur diesel
- Proven in live installations
  - 50 units tested in the field – Alaska to Texas

Tube bundle during assembly

Unit ready for shipment
Gas Utility Module

Water Mass Flow Controller

Anode Fuel Desulfurizer

Anode Fuel Line

Fuel Inlet

Burner Fuel Line
SOFC Applications

- Cathodic Protection (CP)
  - Pipeline & Well Casings
  - Think of it as an “Off Grid Rectifier”

- SCADA
  - Pipeline & Wellhead Instrumentation and Control

- Chemical Injection Pumps
  - Production Wells & Pipelines

- Remote Transmission Sites
  - Telecom Radio Networks
  - Microwave Repeater Sites
This system at a gas distribution site in Massachusetts achieved >12,000 hrs of operation (~1.4 years)
Only emissions from the system is some warm, moist air.

**Natural Gas Pipeline Corrosion Protection Application**
Qualification Site Photos - Gas Utility Located in Massachusetts

System surpassed 12,000 hours of successful operation.

Customer interface box can be configured for specific site application requirements as req'd; power, monitoring & control inputs/outputs.

Fuel input connections use standard, commercial grade meters and valves as used with common natural gas or propane appliances.

Acumentrics
Natural Gas Production Wellhead Application

Acumentrics Remote Power Stations drive Induced Current Cathodic Protection (ICCP) Systems which minimize corrosion of buried pipelines for Natural Gas Pipeline Installers/Operators

Qualification Site located in Texas

Two Acumentrics Remote Power Station Systems
- Solid Oxide Fuel Cell (SOFC)
- 500watt, DC Output (each)
- Natural gas fueled
- Remote monitoring capable
Examples of systems at Texas sites have accumulated ~17,700 hrs of operation & delivered ~5,400 kWh to the customer’s equipment.
Remote Telecom Applications

- Our higher efficiency translates to significant Propane savings for the customer

Potential Annual Fuel Savings = 711 gals/year
At a delivered propane cost of ~$25/gal, fuel savings could be as much as $18,000/year

Two Fuel Cell Generators could be mounted within the solar panel structure

Typical Radio Network Towers in Alaska

Summer

Winter
Power System for Remote Telecom Application
Solar-Battery-Fuel Cell Hybrid Configuration

Solar PV Array

Solar DC Power → DC Charge Controller → 48VDC Battery Bank

Battery Bank sized to power site at full load (1.3kW) for TBD days with zero Solar or FC Input

DC Distribution Panel

Telco Equip DC Load

Telco Equip DC Load

Telco Equip DC Load

Acumentrics RP20 Fuel Cell Modules Deliver 500w Ea

Propane Fuel Storage
Runtime Sealed by Size of Tank:
250 Gal Tank will allow FCs to power site at full load (1.3kW) for ~8 weeks with zero Solar input

Propane Fuel Line

Heat from FC Exhaust could be utilized to keep Battery Bank warm

Typical Operating Mode for a Solar-Battery-Fuel Cell Hybrid System

Advantages:
- Batteries are not deep discharged
- Reserve capacity in batteries can be used for peak power demand to support inrush currents to start Air Conditioners, etc.
- Monitoring “Health” of Batteries & discharge curve is less critical because FC is there to support longer Solar outages
- Solar DC Power input reduces propane consumption and extends time between refueling trips to site
- System designer has option of using a smaller Battery Bank and consuming more propane in the FCs or using a larger Battery Bank and consuming less propane in the FCs. The tradeoff is battery size/maintenance vs. refueling of the propane tank.

www.acumentrics.com   October 2011
<table>
<thead>
<tr>
<th></th>
<th>RP20N1000</th>
<th>RP20P1000</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fuel</strong></td>
<td>Natural Gas</td>
<td>Propane (LP Vapor)</td>
<td></td>
</tr>
<tr>
<td><strong>Fuel Consumption</strong></td>
<td>7 ft³/hr (0.19 m³/hr) (3.2 liters/min)</td>
<td>0.08 gals/hr (0.3 liters/hr) OR 0.34 lbs/hr (0.15 kg/hr)</td>
<td>Nominal at 0.5 kW Steady State Load</td>
</tr>
<tr>
<td><strong>Fuel Cell Capacity</strong></td>
<td>1 kW</td>
<td></td>
<td>Peak Power from Fuel Cell</td>
</tr>
<tr>
<td><strong>DC Output Power</strong></td>
<td></td>
<td>0.5 kW</td>
<td>Maximum Continuous DC Output Power from System</td>
</tr>
<tr>
<td><strong>DC Output Voltage</strong></td>
<td>10 to 48 VDC (User Settable)</td>
<td></td>
<td>Voltage setpoint at factory is determined by Model Number, i.e.: RP20N-1000V28 is set at 28VDC at factory, but output voltage can be adjusted in field within range shown.</td>
</tr>
<tr>
<td><strong>DC Output Current</strong></td>
<td>30A</td>
<td></td>
<td>Maximum Continuous DC Output Current from System</td>
</tr>
<tr>
<td><strong>System Design Life</strong></td>
<td>10 years</td>
<td></td>
<td></td>
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<tr>
<td><strong>Start-up Time</strong></td>
<td>60 minutes</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Efficiency</strong></td>
<td>25%</td>
<td></td>
<td>Nominal at 0.5 kW Steady State Load</td>
</tr>
<tr>
<td><strong>Altitude Range</strong></td>
<td>Sea Level to 3048m (10,000ft)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Environmental</strong></td>
<td>-30°C to +50°C (-22°F to +122°F)</td>
<td></td>
<td>Operating Ambient Temperature Range</td>
</tr>
<tr>
<td><strong>Temperature Range</strong></td>
<td>-40°C to +55°C (-40°F to +131°F)</td>
<td></td>
<td>Non-Operating, Storage Temperature Range</td>
</tr>
<tr>
<td><strong>Physical Dimensions</strong></td>
<td>22.2in x 22.5in x 39.4in (11.4 ft³) (564mm x 571mm x 1000mm) (0.3m³)</td>
<td></td>
<td>Does not include fuel tank</td>
</tr>
<tr>
<td><strong>Weight</strong></td>
<td>300lbs (136kg)</td>
<td></td>
<td>Extended Warranty Available</td>
</tr>
<tr>
<td><strong>Warranty</strong></td>
<td>1 year standard</td>
<td></td>
<td>Standard annual PM consists of changing air filters, clean and check fuel filters, etc. Fuel cell bundle is rated for minimum of one year of life or 8,760hrs. If required, stack bundle can be replaced onsite during annual maintenance visit and takes ~3 hours.</td>
</tr>
<tr>
<td><strong>Preventative</strong></td>
<td></td>
<td>Annual Service Visit</td>
<td></td>
</tr>
<tr>
<td><strong>Maintenance</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Communications</strong></td>
<td></td>
<td>Local collection and storage of system data is standard and can be accessed thru Ethernet cable connection and/or transmitted through a satellite link or cellular network.</td>
<td></td>
</tr>
<tr>
<td><strong>Modularity</strong></td>
<td></td>
<td>Systems can be operated with their outputs connected in parallel for higher output power applications</td>
<td></td>
</tr>
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Remote Monitoring & Control via Satellite Link or Cellular Network

Typical Weekly Performance Chart

- Voltage Out
- Current Out
- Fuel Flow
- Power Out (W)

<table>
<thead>
<tr>
<th>Date</th>
<th>03/18/11</th>
<th>03/19/11</th>
<th>03/20/11</th>
<th>03/21/11</th>
<th>03/22/11</th>
<th>03/23/11</th>
<th>03/24/11</th>
<th>03/25/11</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volts, Amps, Fuel Flow</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power Out (W)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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Thank You.....................Questions?

For more info and to download datasheet & related documents:

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