Hydrogen and Fuel Cells for Resiliency: Microgrids for Grid Power

June 16, 2016
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Submit your questions at any time by typing in the Question Box and hitting Send.

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**Resilient Power Project**

- Increase public/private investment in clean, resilient power systems
- Engage city officials to develop resilient power policies/programs
- Protect low-income and vulnerable communities
- Focus on affordable housing and critical public facilities
- Advocate for state and federal supportive policies and programs
- Technical assistance for pre-development costs to help agencies/project developers get deals done
- See [www.resilient-power.org](http://www.resilient-power.org) for reports, newsletters, webinars, and more.
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Northeast Electrochemical Energy Storage Cluster (NEESC)

NEESC is a network of industry, academic, government and non-governmental leaders working together to help businesses provide energy storage solutions.

www.neesc.org
Today’s Guest Speakers

• **Robert Rose**, Vice President, A-Z Corp

• **Ben Toby**, Vice President of Sales, FuelCell Energy
Hydrogen & Fuel Cells for Resiliency: Microgrids for Grid Power

June 16, 2016

Ben Toby
FuelCell Energy, Inc.

Robert Rose
A/Z Corporation
Microgrids

- Interconnected Loads
- Distributed Generation
  - Fuel Cell
  - Reciprocating Engine
  - Gas Turbine
  - Micro-Turbine
  - Renewables
    - PV
    - Wind
    - Energy Storage
- Defined Electrical Boundaries
- Single Controllable Entity
Define Overall Objective(s)

- Critical Facility
- Existing infrastructure
- Financial Options
- Technical Requirements
  - Electrical Distribution
  - Thermal Distribution
  - Fuel Source

Daegu, South Korea, 11.2 MW
Why Fuel Cells?

- Energy Cost Savings
- Reliable, Grid Independent
- Clean, Quiet & Efficient
- Fuel Flexible
- Permitting and Siting Ease

Hartford Hospital, 1.4 MW

Central CT State University, 1.4 MW

<table>
<thead>
<tr>
<th>Power Source</th>
<th>Efficiency (%)</th>
<th>NOx (lb/MMBtu)</th>
<th>SOx (lb/MMBtu)</th>
<th>PM&lt;sub&gt;10&lt;/sub&gt; (lb/MMBtu)</th>
<th>CO₂ (lb/MMBtu)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average U.S. Grid</td>
<td>33%</td>
<td>3.43</td>
<td>7.9</td>
<td>0.19</td>
<td>1,408</td>
</tr>
<tr>
<td>Average U.S. Fossil Fuel Plant</td>
<td>36%</td>
<td>5.06</td>
<td>11.6</td>
<td>0.27</td>
<td>2,031</td>
</tr>
<tr>
<td>DFC&lt;sup&gt;®&lt;/sup&gt; Fuel Cell on Nat Gas</td>
<td>47%</td>
<td>0.01</td>
<td>0.0001</td>
<td>0.00002</td>
<td>940</td>
</tr>
<tr>
<td>DFC&lt;sup&gt;®&lt;/sup&gt; Fuel Cell on Nat Gas (CHP)</td>
<td>80%</td>
<td>0.006</td>
<td>0.00006</td>
<td>0.00001</td>
<td>550</td>
</tr>
<tr>
<td>DFC&lt;sup&gt;®&lt;/sup&gt; Fuel Cell on Biogas (CHP)</td>
<td>80%</td>
<td>0.006</td>
<td>0.00006</td>
<td>0.00001</td>
<td>0</td>
</tr>
</tbody>
</table>

Source for non-DFC data: "Model Regulations For The Output Of Specified Air Emissions From Smaller-scale Electric Generation Resources: Model Rule and Supporting Documentation", October 15, 2002; The Regulatory Assistance Project report to NREL.
The DFC®1500 stationary fuel cell power plant from FuelCell Energy provides high-quality, Ultra-Clean electrical power with 47% efficiency, and high quality exhaust heat suitable for hot water, steam, or absorption chilling applications, around the clock. Designed for commercial and industrial applications, the system offers easy transport, quiet and reliable operation, and simple site planning and regulatory approval. The DFC1500 is ideal for wastewater treatment plants, manufacturing, food and beverage processing, universities and office campuses.

### Gross Power Output
- **Power @ Plant Rating**: 1,400 kW
- **Standard Output AC voltage**: 480 V
- **Standard Frequency**: 60 Hz
- **Optional Output AC Voltages**: By Request
- **Optional Output Frequency**: 50 Hz

### Efficiency
- **LHV**: 47 +/- 2 %

### Available Heat
- **Exhaust Temperature**: 700 +/- 50 °F
- **Exhaust Flow**: 18,300 lb/h
- **Allowable Backpressure**: 5 iwc
- **Heat Energy Available for Recovery**:
  - (to 250 °F): 2,216,000 Btu/h
  - (to 120 °F): 3,730,000 Btu/h

### Pollutant Emissions
- **NOx**: 0.01 lb/MWh
- **SOx**: 0.0001 lb/MWh
- **PM10**: 0.00002 lb/MWh

### Greenhouse Gas Emissions
- **CO2**: 980 lb/MWh
- **CO2 (with waste heat recovery)**: 520-680 lb/MWh
FuelCell Energy’s DFC3000™ system is the largest of the Direct FuelCell® (DFC®) power plant fleet, capable of providing high-quality baseload power with 47% electric power generation efficiency around-the-clock. Scalable for Multi-Megawatt Fuel Cell Parks, the system is especially suitable for applications with larger load requirements such as universities, manufacturing facilities, wastewater treatment plants, and utility/grid support.

### Gross Power Output
- **Power @ Plant Rating**: 2,800 kW
- **Standard Output AC voltage**: 13,800 V
- **Standard Frequency**: 60 Hz
- **Optional Output AC Voltages**: By Request
- **Optional Output Frequency**: 50 Hz

### Efficiency
- **LHV**: 47 +/- 2 %

### Available Heat
- **Exhaust Temperature**: 700 +/- 50 °F
- **Exhaust Flow**: 36,600 lb/h
- **Allowable Backpressure**: 5 iwc
- **Heat Energy Available for Recovery**
  - (to 250 °F): 4,433,000 Btu/h
  - (to 120 °F): 7,460,000 Btu/h

### Pollutant Emissions
- **NOx**: 0.01 lb/MWh
- **SOx**: 0.0001 lb/MWh
- **PM10**: 0.00002 lb/MWh

### Greenhouse Gas Emissions
- **CO2**: 980 lb/MWh
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Direct FuelCell® Power Plant

Key

- Fuel cell module
- Mechanical Balance of Plant (MBOP)
- Electrical Balance of Plant (EBOP)
- Water Treatment
- Blower, Heater, Fuel Preconverter
- Heat Recovery Unit (CHP)
- Inverter
- Switchgear
- 1.4 MW Stack Module
Levelized Cost of Electricity

Levelized Cost of Energy - unsubsidized

- **FuelCell Energy**: $0.12
- **Central generation**: $0.06 - $0.15 + T&D
- **Solar PV: NE-USA**: $0.10 - $0.22 + peaking + T&D
- **Solar PV: SW-USA**: $0.08 - $0.17 + peaking + T&D
- **Gas Peaking Power**: $0.18 - $0.23 + T&D
- **WIND: SE-USA**: $0.08 - $0.12 + peaking + T&D
- **Wind: MW-USA**: $0.04 - $0.06 + peaking + T&D
- **Transmission (T&D)**: $0.02

Based on $4.50/million Btu gas cost; each $2/million Btu change equates to one penny for FCE LCOE. Source: Company estimates, Lazard LCOE v. 8.0, EIA, Oak Ridge National Lab.

Renewable Energy Credits (RECs), Federal Investment Tax Credit (ITC) and Heat Use enable LCOE ~ $0.09/kWh
Fuel cells provide dependable, clean electricity and heat for microgrids, either alone or in parallel with other generation sources.

**Grid Connected mode**
In normal operation the fuel cell synchronizes to local utility grid and offsets part or all of the load demand of the facility, reducing power needed from the utility.

**Microgrid mode**
After a grid outage, facility loads see a brief interruption, and are then reconnected in a controlled manner to the fuel cell and other on-site sources.

**Critical Supply mode**
Upon grid outage, disconnects from the grid and enters standby mode. Seamless backup power available to hard-wired customer critical loads up to 85% of fuel cell output.

**Load Leveler operation profile:**
Microgrid established in ~30 seconds.
Grid Connected Mode

Powerplant synchronizes to local utility grid and reduces local power demand or exports power to grid. Grid must meet stringent requirements for voltage and frequency or powerplant will disconnect and go into grid independent mode.

- Baseload, Full Power Production
- Current Control Mode
- Match & Follow Grid Voltage
- UL-1741 Anti-Islanding Detection
  - Abnormal Volt. & Freq.
  - Active anti-islanding algorithm
Micro-Grid Mode
Powerplant synchronizes to microgrid either as a baseload current source, reducing output from local power generation systems, or as a load following voltage source in parallel with other local generators or as a stand-alone generator.

Current Source Micro-Grid Mode
- Gen set connects to bus at rated voltage and freq
- DFC syncs with gen set and connects to bus with wider V&F relay settings and active anti-islanding disabled.

Voltage Source Micro-Grid Mode
- Multiple fuel cells or fuel cell / gen set combination.
- No master sync setting, units synchronize autonomously
- Compliant with CERTS philosophy
Critical Supply Mode
Powerplant is not connected to grid, generates its own frequency signal. Supports powerplant parasitic loads in standby mode, and can support local critical loads.

Upon detection of abnormal Voltage & Frequency:
- Tie Breaker Opens
- Switch to Voltage Control Mode
- Parasitic and Critical loads recovered <4 cycles
All DFC plants are capable of generating rated output from better than (-) 0.9 to (+) 0.9 pf
  • 2.8 MW System can provide more than 2 MVAR @ 2800kW, with higher reactive capabilities at lower kW output

By supplying reactive current locally, less KVA is needed from the local utility or micro grid system.
  • Frees up capacity in the local grid or micro-grid.
  • Reduces total electric system losses
  • Fast and precise power factor correction
Project Overview

• 1.4 MW combined heat & power fuel cell power plant
• Supplies 80% of campus power needs
• Waste heat converted to hot water and supplied to three locations on campus

Benefits

• ~20% cost savings during normal operations
• In a grid outage, power to critical facilities – shelter, security, dining
• Renewable Energy Research Lab – “practice what we teach”
• Emissions reductions: 7,000 tons CO2, 64 tons SOx, 28 tons NOx
Fuel Cell only
• 1.4 MW Fuel Cell
• Load Follow Capable
• Black-Start Capable

Grid Connected Operation
• Base Load, Net Metering
• Heat to Campus

Microgrid Operation
• “Drop & Pickup”
• Microgrid controller sequences critical facilities
• Inverter follows microgrid load
• Load Leveler maintains fuel cell power constant
**Project Overview**

- 2.2 MW combined heat & power fuel cell power plant
- Power to UI grid during normal operation
- Supplies 100% of Town microgrid power needs during grid outage
- Heat supplied to Amity High School
- Connecticut Microgrid Program Award

**Benefits**

- Helps UI achieve its Class I RPS goals
- In a grid outage, power to critical facilities – police, fire, community services
- Savings to Amity High School ~ $100K per year from avoided natural gas
- Enabled upgrade to local gas grid delivery infrastructure
Fuel Cell only
- 2.2 MW Fuel Cell
- Hot water to High School
- Load Follow Capable
- Black-Start Capable

Grid Connected Operation
- Base Load
- Heat to High School

Microgrid Operation
- “Drop & Pickup”
- Microgrid controller sequences critical loads
- Inverter follows microgrid load
- Load Leveler maintains fuel cell power constant
Pfizer R&D Center, Groton CT

**Project Overview**
- Grid-connected 5.6 MW fuel cell powered by Natural Gas
- Provides electricity and steam to Pfizer Groton campus
- Seamless grid independent capability
- Private, Critical Facility Microgrid

**Benefits**
- Closes electrical generation gap with a more reliable source than the commercial grid – makes site independent year round
- PPA structure with no up-front capital cost, delivers energy cost savings to Pfizer
- Enhances site sustainability profile (green energy source)
- Clean profile reduces permitting hurdles
Fuel Cell – Gas Turbine
- 10 MW Gas Turbine
- (2) 2.8 MW Fuel Cells
- Load Follow Capable
- 2 Levels of Seamless Backup.

Microgrid Operation
Loss of Utility
- Seamless disconnect from utility
- FC base load
- Turbine Load Following
Loss of Gas Turbine & Utility
- Seamless disconnect from Campus.
- FC maintains critical building loads.

Grid Connected Operation
- Fuel Cells Base Loaded
- Steam to Campus
- Gas Turbine follows campus load to maintain zero utility import/export.

Public Utility
Campus Point of Interconnection
Campus 13.8 kV Distribution System

10 MW Gas Turbine
2.8 MW Fuel Cell
Buildings Loads <2.5 MW
ATS
CB
ATS
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Fuel cell advantages in microgrids:
- Low emission, quiet distributed generation solution
- High efficiency, low carbon
- Reactive power support
- Energy Cost savings

Technology proven and gaining acceptance globally

Complex projects requiring staged development with CHP as the cornerstone

Clean, Efficient & Financeable
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