Hydrogen power system for remote applications

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Hydrogen Power System for Remote Applications

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Overview

- Project description and objectives
- System description
- Field site testing
- Results to date
- Current Work
Project Description

10,000 Off-Grid locations in Nevada with a cost of up to $500,000 to be on the grid

Multi-phase effort to develop a cost-effective renewable H2 based off-grid-power system for rural Nevada and the Southwest

• System attributes:
  – Renewable energy (solar and wind) to generate hydrogen using an electrolyzer and store energy in a battery bank
  – Dual fuel ICE (H2 and propane) for power generation
Project Objectives

• Investigate the application of H2 off-grid power generation using renewable energy
• Optimize the integrated system
  – Increased energy storage as H2
  – Embedded controller for maximum efficiency and minimal human interface
• Study the use of a compact proton exchange membrane (PEM) electrolyzer
• Evaluate system performance in a real-world, off-grid application
Trailer Components

• 12 Foot Wells Cargo enclosed trailer
• Outback Power Systems 48 VDC/120VAC dual inverter unit
• Twelve 12VDC Gelled Electrolyte Batteries providing 1.3 kWhr of stored energy
• 600 cc/min 200 PSI PEM Electrolyzer
• 4 110 ft^3 storage tanks holding .2 kg of Hydrogen
• Converted Lister Petter 2 cylinder, 4 stroke engine and 1800 rpm 3 kWe generator
System Schematic

- Solar Panels
- Electrolyzer
- Hydrogen Tanks
- ICE Generator
- Propane Tanks
- 48V Bus Bar

Direction of Energy Flow

- Residential House via Inverters
- Deka Photovoltaic Gel Batteries

NEVADA Southwest Energy Partnership
Engine Control Logic

- **Battery Voltage**
  - Continue Current Operation if <44 VDC
  - Engine On if H2 > 20 PSI and Less than 20% gases in the air

- **Battery Current >3**
  - Renewable Energy is charging batteries and Electrolyzer is turned on to a certain power level depending on the current
  - Power System Shutdown when Battery Voltage reaches 43 VDC

- **Fuel = Propane**
  - Propane >30 PSI and Less than 20% gases in the air
  - Absorb Engine Stage until battery voltage absorbs voltage setpoint or 25 minutes

- **Fuel = Hydrogen**
  - Fuel = Hydrogen
  - Float Stage Engine on for same time as absorb stage

- **Batteries are supplying power to the load**

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**Southwest Energy Partnership**
Weather based System Controls

1. Downloaded Weather Data File from NOAA.
2. Select required Wind & Solar Data.
3. Calculate net available renewable power by subtracting calculated renewable power from average seasonal load.
4. If ZERO
   - No action undertaken. H2 neither produced nor consumed.
5. Multiply Actual Available Renewable power w/ Electrolyzer Effn. to calculate Hydrogen Produced.
6. Add Hydrogen already available
7. Hydrogen generated for next 54 hours.
8. Calculate Final Hydrogen available
10. If NEGATIVE
   - Required power is compensated from batteries. ICE Gen starts when batt discharge condition is met.
11. Calculate respective fuel used using required power & ICE Gen Effn w/ respective fuel.
12. Hydrogen used over next 54 hours
13. Final Propane available
Trailer
Field Test Site #1

- Galena, NV
- 6 Solar thermal panels
- Passive solar
- PV-Direct well
- Two 1.5 kW tracking solar arrays
- Average winter house load of 21 kW/day
Test Site #2

- Two 1 kW solar arrays
- Two 1.5 kW wind turbines
- 5 kW KOH Electrolyzer producing 0.1 kg/hr hydrogen
- Average Summer power demand of 6-7 kWhr/day
Test Site #1 Operation

- Over 30 days of operation at test site from February into March
- One 1.5 kW solar array available for power system
- Limited electrolyzer capacity
Test Site #1 Results

• 1.5 kWe rated solar array observed up to 1.3 kWe
• 6 engine cycles per day to meet the winter load demand
• 40-90 minute engine cycles
• 2-2.5 kg of Hydrogen necessary
• Sufficient data for system evaluation
Upgrades for test site #2

• Engine
  – Retuned
    • Including spark timing maps
  – Removed turbocharger

• Better H2 production control

• Convert DRI Renewable to 48 VDC

• Appropriate Load Profile

• Simplified Software program
Test Site #2 Operation

- Easily observed at DRI location
- 1 array powering PEM electrolyzer
- 1 array and wind turbines for KOH electrolyzer
- Over 20 days of summer data
Test Site #2 Results

- PV array producing over 700 Watts continuously
- 2 Engine cycles per day at 50 minutes and .32 kg per cycle
- Engine efficiency normal for engine size
  - 11-18% on hydrogen
- PEM electrolyzer produced up to 560 cc/min drawing 500 W
**Site #2 Requirements**

### 6.5 kW 24-hour Summer Load Profile

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Quantity</th>
<th>Supplied Power (kW)</th>
<th>Power Consumption (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Renewable Energy</td>
<td>Solar or Wind</td>
<td>3</td>
<td>3.00</td>
<td></td>
</tr>
<tr>
<td>Battery</td>
<td>12 VDC Gelled Electrolyte</td>
<td>12</td>
<td>1.3</td>
<td></td>
</tr>
<tr>
<td>Electrolyzer</td>
<td>Proton Energy HOGEN 600</td>
<td>2</td>
<td></td>
<td>3 kW</td>
</tr>
<tr>
<td>H2 Storage</td>
<td>200 PSI storage tank 1 m³</td>
<td>1</td>
<td>(.66 kg/day H₂ in Summer)</td>
<td>90,000 BTU Hydrogen</td>
</tr>
<tr>
<td>Engine</td>
<td>ListerPetter 2 cylinder Genset</td>
<td>1</td>
<td>3- Propane 2.5- Hydrogen</td>
<td>.32 kg/cycle, 1 cycle is 50 minutes, 2 cycles per day</td>
</tr>
<tr>
<td>Propane Backup</td>
<td>25 lb. Propane Tank</td>
<td>2</td>
<td></td>
<td>1,000,000 BTU</td>
</tr>
</tbody>
</table>
Fuel Efficiency

Power Output
Fuel Energy

Hydrogen
Propane

Efficiency %

Load [kW]
Summary 1

Ideal Situation
• 2 Electrolyzer’s
• 1 m$^3$ or .7 kg hydrogen storage
• 3 kW renewable energy in summer would require minimum propane use
Summary 2

- Developed and tested mobile renewable energy power system
- Unique aspects include hydrogen production, dual fuel ICE, mobile unit
- Limitations of electrolyzer and engine design
- Current work includes more control over different fuels in ICE, Maximizing engine performance, more efficient system control, ultra capacitors, and hydrogen production/storage options
Questions