Field Test Experience with Areva's PEM Electrolysis Systems

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AREVA in Germany short information

- Smart Grid Solar Project – AREVA Scope - The hydrogen chain
- Close up: The AREVA PEM electrolyser used in the project
- The PEM electrolyser in the field – measurements from the testfield Arzberg
AREVA in Germany

4,100 AREVA-Employees in Germany (41,000 worldwide)

Sales in Germany (2014)*: 1.1 Billion €
(Germany 29%, Export 71%) (8.3 Billion € worldwide)

* IFRS

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ZAE SMART GRID
Solar Project in Germany

www.smart-grid-solar.de
The hydrogen chain

„Green production“
• „green“ production of hydrogen (Solar, wind turbine)

→ $\text{H}_2/\text{O}_2$ production via water electrolysis
• Hydrogen as energy storage (electricity storage, thermal use, grid stabilization)

→ Multiple-use applications
• Hydrogen as a substitute of fossil fuels (Cars, Fuel Cell utility vehicles, Electricity-/H$_2$ – gas station)
• Power to Gas
• Power to Chemicals
The hydrogen chain at the Smart Grid Solar Project

75 kW PEM Elektrolyzer
Hydrogen production

- Smoothing of fluctuating PV-grid fed in profiles
- Dynamics of a PEM ELY
- Efficiency at partial load
- Combination of short/long-term storage components

300 kWh LOHC* Storage
Long-term storage

- Performance of LOHC storage
- Steady hydrogen production for seasonal storage
- Cycle stability of LOHC
- Degradation LOHC
- Technology field test (TRL 7)

5 kW Fuel Cell
Reconversion

- Dynamics of PEM fuel cell
- Extension of feed-in times (virtually)
- Combination of short/long-term storage components

*) LOHC = Liquid Organic Hydrogen Carrier
The hydrogen chain at the Smart Grid Solar Project

**Electrolyzer**
- **η = 70%**
- 30 bar
- 50 kW – 75 kW
- Hydrogen (H₂)
  - 10-15 Nm³/h
- Water (H₂O)
  - 10 l/h

**Hydrogenation**
- **4 kWh/kg H₂ binding energy**
- 1.3 kg H₂ / h = 24 l LOHC
- Oxygen from ambient air (O₂)
- LOHC storage (scalable)
  - 150 l = 300 kWh

**Dehydrogenation**
- **9 kWh/kg H₂ binding energy**
- 0.3 kg H₂ / h = 8 l LOHC
- Water (H₂O)
- Waste (Heat)

**Fuel Cell**
- **η = 50%**
- 5 kW
- 1.3 bar
- Electricity 5 kWh
- Water (H₂O)
- Waste (Heat)

**Electricity** (renewable)
- Wind, PV, etc.
- 50 kW – 75 kW
- Waste (Heat)

**Oxygen** (O₂)
- 5-7.5 Nm³/h
75 kW PEM Elektrolyseur

Wasserstoffverzeugung

300 kWh LOHC* Speicher

Langzeitspeicher

5 kW Brennstoffzelle

Rückverstromung

Themen für die Komponententests:

- Glättung von unsteten PV Einspeiseprofilen
- Dynamik eines PEM ELY
- Effizienz unter Teillast
- Kombination Kurzzeit-Langzeit Speicherkomponenten

*) LOHC = Liquid Organic Hydrogen Carrier

- Betriebsverhalten LOHC Speicher
- Konstante Wasserstoffproduktion als Saisonalspeicher
- Zyklustabilität LOHC
- Degradation LOHC
- Technologie Feldtest (TRL 7)

Dynamik der PEM BZ
- Virtuelle „Einspeiseverlängerung“ (in die Nacht)
- Kombination Kurzzeit-Langzeit Speicherkomponenten

The hydrogen chain at the Smart Grid Solar Project
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### Details and characteristics of the electrolyser

<table>
<thead>
<tr>
<th>No.</th>
<th>Characteristics Stack design: 65 cells, active surface 300cm²</th>
<th>Measured values</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Nominal flowrate: 10Nm³ H₂/h (370 amp in the stack)</td>
<td>370 amp</td>
</tr>
<tr>
<td>2</td>
<td>Maximum flowrate: 15Nm³ H₂/h (550 amp in the stack)</td>
<td>520 amp /14.2Nm³ H₂</td>
</tr>
<tr>
<td>3</td>
<td>Nominal Pressure: 35barg H₂ for 75kW</td>
<td>80kW 35 barg H₂, 34 barg O₂</td>
</tr>
<tr>
<td>4</td>
<td>Overall electrical consumption &lt; 5kWh/Nm³ at nominal flowrate</td>
<td>ok</td>
</tr>
<tr>
<td>6</td>
<td>Operating range (in % of nominal flowrate): 10-150%</td>
<td>ok</td>
</tr>
<tr>
<td>7</td>
<td>Power from local grid connexion 400V TRI</td>
<td>395V</td>
</tr>
<tr>
<td>8</td>
<td>CE certification</td>
<td>ok</td>
</tr>
</tbody>
</table>
## Characteristics measurements from factory acceptance test

<table>
<thead>
<tr>
<th>N°</th>
<th>Step</th>
<th>Supply</th>
<th>Value obtained</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Start up set</td>
<td>Time (s) to contactor (first current on the stack) closure to reach set power (50 kW), starting at 0barg</td>
<td>~ 95sec</td>
</tr>
<tr>
<td>2</td>
<td>Power range</td>
<td>Average value of cells voltage at 550 amp (74,7kW, 14,11Nm³/h, 524A)</td>
<td>130V/65 cells</td>
</tr>
<tr>
<td>3</td>
<td>Stand by &gt;12h</td>
<td>Pressure loss during longterm hot stand-by H₂ and O₂ pressure curves in function of time</td>
<td>H₂ &lt; 2.5 bar</td>
</tr>
<tr>
<td>4</td>
<td>Hot stand-by max</td>
<td>Time (s) to contactor (first current on the stack) closure to reach maximum power (75 kW), starting at 35barg</td>
<td>~14sec</td>
</tr>
<tr>
<td>5</td>
<td>Cold stand-by max</td>
<td>Time (s) to reach 35barg at maximum power (75kW)</td>
<td>~ 5min 44sec</td>
</tr>
</tbody>
</table>

- **No 3**:
  - H₂: Pressure loss overnight < 2.5 bar
  - O₂

- **No 5**:
  - From 0 to 35 barg ~ 5min
  - H₂
  - O₂
  - kW

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Delivery and installation of the PEM Electrolyzer, 65 cells, 300cm², 35 bar
Measurements from the testfield in Arzberg: Dynamics: Following the PV-Profile

Nachfahren eines PV-Profils vom 13.05.2015

The PEM electrolyzer follows volatility without problems
Dynamic H2 und O2 production from „green electricity“
Measurements from the testfield in Arzberg:
Efficiency complete system vs. hydrogen production

High efficiency over a large operating range, highest efficiency at the design point

Step profile for different set points

Design point (10Nm³/h; 73% eff)

Effizienz Gesamtsystem  Hocheffizienter Betriebsbereich (>70%)  H2 Produktion

All values based on heating value (HHV – 3.54 kWh/Nm³)
Measurements from the testfield in Arzberg:

Energy consumption stack vs total system
Measurements from the testfield in Arzberg: U-I curves and temperatures

- Each measurement = 1 dot
- T values taken every second at the stack outlet
- Cold temp = start ups
- Isoline stripes = process control keeps the DC power to the set value because \( U_{DC} \cdot I_{DC} = \text{const} \)
Thank You for the attention!

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