Water Electrolyzer Technology: Status and Challenges

H2@Scale Workshop
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Outline

- Giner, Inc./Giner ELX, Inc. Intro
- Status of current electrolyzer technologies
- ‘Giner’ PEM electrolyzer technology
  - Product road map & projects
- Electrolyzer Technology - Challenges & Needs
  - Manufacturing
  - Scalability
  - Testing Equipment & Validation
  - R&D needs for emerging electrolyzer technologies
  - Grid Integration
  - Collaboration
Giner, Inc. Founded in 1973
- Specializing in research & development of PEM based electrochemical technology and systems
- Since 2005 Giner has accelerated growth
  - Key driver has been the manufacturing of PEM electrolyzers to OEMs
  - Global leader in Polymer Electrolyte Membrane (PEM)-based electrolyzers
  - Highest efficiency technology for commercial applications
- Core Mission: Provide Innovative PEM Technologies with the Highest Efficiencies at the Lowest Costs to Developing Hydrogen Markets
- In April 2017, GINER ELX, Inc. was created to focus on commercial development and manufacturing of large scale electrolyzer stacks & systems
## Status of Current Electrolyzer Technologies

<table>
<thead>
<tr>
<th>Electrolysis Technology</th>
<th>Production Rate (kg/day)</th>
<th>Pressure (bar)</th>
<th>Temp (°C)</th>
<th>Eff (%HHV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alkaline</td>
<td>1500+</td>
<td>700+</td>
<td>30</td>
<td>40-90</td>
</tr>
<tr>
<td>PEM</td>
<td>475</td>
<td>220</td>
<td>40-100</td>
<td>20-90</td>
</tr>
<tr>
<td>Solid Oxide</td>
<td>~2</td>
<td>1+</td>
<td>Atm</td>
<td>600-1000</td>
</tr>
<tr>
<td>HT-Alkaline</td>
<td>~2</td>
<td>1+</td>
<td>30+</td>
<td>50-80</td>
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</tbody>
</table>

**Maturity**

Alkaline: 350-600

*Sources: Courtesy MCPHY*
Emerging Markets & Drivers

- Power to Gas (P2G): Vast opportunities in Biogas
- Power to Mobility (P2M)
- Power to Hydrogen (P2H) 
  Integration of Renewable Energy Sources
  - Large reserves of stranded energy (need to store/shift)
    - Ongoing broad developing wind energy sector
  - Backup power for grid outages and load shedding

220+ Nm³/hr (MW Scale)

30 Nm³/hr

3 Nm³/hr

0.05 Nm³/hr

Aerospace/Military Applications

Commercial/Industrial Applications
New Designs for Future Applications

New Market Trends Require Larger Stacks

- 5MW Stack Platform
  - Operating Pressure: 600 psig
  - Active Area: 3,000+ cm²
  - Current Density: 3,000+ mA/cm²
- Development 2018/19
- Economics
  - Accelerates market opportunities
Large Scale Systems for Mobility

Giner 500 kW HRS System - Mobile Refueling

Cost Contributors & Needs

BOP
Understanding Standards/Codes
System simplification
Component availability & cost

Electrical
Rectifier cost
Redundancy
Rapid power switching for RES

Stacks
Scale up
Product Roadmap


Manufacturing & Sales
50kW – 150kW
(24 – 65 kg/d) Stacks

130 – 260 kg/d Systems
CA H₂ Refueling Stations

1 MW (480 kg/d) Stack
Development & System Integration

MW Stack (480 kg/d) & MW System Sales “P2G”

MW System Demonstrations

Multi-MW to GW Demo’s
(4,800 kg/d to 480,000 kg/d)
Systems Integration
### Recent Projects

<table>
<thead>
<tr>
<th>Flag</th>
<th>Project Description</th>
</tr>
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<tbody>
<tr>
<td>🇺🇸</td>
<td>On-site Hydrogen Generation HRS in CA (3x200 kg/d)</td>
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<tr>
<td>🇩🇪</td>
<td>Bio-Methane (240 kg/d) Phase I finished 2014 &amp; P-II 2016</td>
</tr>
<tr>
<td>🇪🇸</td>
<td>65 kg/d Hydrogen Refueling Station in Spain - Follow up Projects Multi-MW</td>
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<tr>
<td>🇫🇷</td>
<td>200 kg/day H₂ Generator Subsystem 2017 France - Major Utility company</td>
</tr>
<tr>
<td>🇮🇳</td>
<td>System to India - Mobile Refueling, Follow up order 200 kg/day</td>
</tr>
<tr>
<td>🇩🇪</td>
<td>Supplying stacks to integrators - Industrial use. Follow up orders for 300 kg/day</td>
</tr>
</tbody>
</table>
Electrolyzer Technology Challenges & Needs

- Manufacturing
- Scalability
- Testing Equipment & Validation
- R&D needs for emerging electrolyzer technologies
- Grid Integration
- Collaboration
Challenges: Manufacturing

Manufacturing Innovations Required

- MEAs
  - Lack quality inspection - leaks, pinholes, and shorts
  - Lack of MEA assembly processes (alignment of electrodes)
  - Lack of high rate pressing/lamination processes
  - Lack of high quality cutting processes
- Electrodes
  - Lack of uniformity and quality of coatings
  - High scrap rates associated with decal transfer coating
  - Lack of manufacturing processes for scaling catalysts batches
  - Lack of performance-based tolerances
  - Lack of continuous catalyst ink processing
  - Lack of high throughput heat processing

- Cell Components
  - High cost of production equipment
  - Lack of plate joining processes

- Stack Assembly
  - Lack of methods to ensure alignment of cells during assembly
  - Lack of high rate stack sealing processes
  - Lack of methods to handle soft, flexible components during automated stack assembly
Challenge: Scalability

Stack Design(s)
- Cell materials not available for larger active areas
  - Alternative support materials
- New tooling to develop components for scaled-up cell areas
  - Injection molds, membrane support materials

Production Line(s)
- Need to align MW design(s) across company product lines
  - Simplifies supply chain and inventory management
  - Improves production efficiency
    - Reduces scrap
    - Reduces labor content
    - Eases training and QC/QA
    - Improves internal supply chain
- MW Scale Stacks require implementation of new manufacturing processes or process improvements
  - Automated catalyst decal preparation
  - Cell component unitization
  - MEA Automation/Roll-to-Roll
  - Stack assembly automation

Regulation
- Certification requirements: MW stacks need to be compliant with pressure directives, CE, UL…
Challenge: Testing Equipment

Scale-up to MW Stack also requires scale-up of testing equipment!

Test equipment requirements:

- High differential pressure capabilities
  - $\text{H}_2$: 0 - 100 bar
- Large power requirements
  - Stack sizes to 5 MW+
- New Evaluation methods:
  - Membrane performance
  - Durability
  - Lifetime
- Safety!
  - Availability of High Voltage, High Pressure Equipment
  - Employee Training
Challenge: Validation of Large Scale Electrolyzers

New Test Facilities required as larger stacks come online...

- MW stack testing limited to facility power
  - Limits stack size (or number of cells) that can be tested
- Large cost to increase power into a facility
- Heavy lifting equipment required

Short-stack testing of Giner’s MW platform, 100 kW required for 6 cells, weight 2500 kg
Challenges: Emerging Electrolyzer Technologies

Low Temperature Electrolysis (AEM)

**Advantage**
- Low CapEx: Use of non-noble metal catalyst

**Needs:**
- **Efficiency improvement**: development of catalyst & alkaline membranes
  - Performance target: 2.0 V @ 600 mA/cm²

High Temperature Electrolysis (HT Alkaline)

**Advantage**
- Low OpEx: Use of high temperature sources - Improved efficiency

**Needs:**
- **Life time improvement**: Development of new electrolyte matrices resistant to molten hydroxides (α-Al₂O₃ typically used)
- **Performance improvements**:
  - Area-specific resistance (ASR) of ≤ 0.2 Ohm-cm² at 350 to 550 °C.
  - Increase Stack electrical efficiency & CD: > 90% LHV H₂ at 1.2 A/cm²
- **Heat Sources**: Renewable/Nuclear/Industrial

Need to identify degradation mechanisms (see 2017 AMR presentations: PD143 & FC 129)
Challenge: R&D Needs for emerging technologies…

…will shadow methods used in PEM electrolysis

- Low Temp AEM- Needs:
  - Efficiency improvements
    - Continued development in non-PGM catalysts & alkaline membranes

- Hi-Temp Alkaline/SO Needs:
  - Durability improvements (matrix)
  - Designs that operate at higher pressure
    - Sealing

Stacks need to be designed with fewer components to reduced cost and ensure competitiveness on a larger scale.

There is a need to Reduce Part Counts to decreases labor/fabrication costs and enable Automation.

Addition info: [https://www.hydrogen.energy.gov/pdfs/revie w13/pd030_hamdan_2013_o.pdf](https://www.hydrogen.energy.gov/pdfs/review13/pd030_hamdan_2013_o.pdf)
Challenges: Grid Integration (w/RES)

- Wind-to-Hydrogen gaining momentum
  - Systems & demos that address
    - Costs
    - Capacity factors
    - Optimization
    - Integration of wind turbine and electrolyzer control systems

- Optimized placement of plant
  - Centralized hydrogen production
  - Adjacent wind farm
    - Future pipeline network?

- Cost performance models
Challenges: Coordination

Develop roadmap for renewable electrolysis • Coordination, Planning, and Stakeholder Development

- Ideal Location site
- Wind / Solar Farm

- Equipment & Labor

- Tax Incentives & regulatory support

Utility Co.

Electrolysis Manufacturers + Engineering Construction Firms

Install equipment, characterize performance, and develop standard test procedures for renewable electrolysis systems

Legislative Bodies

Auto Manf.

Work with industry on developing hardware and control strategies to couple RES to electrolyzers

H₂@Scale Coordinator

• Funding to enable Infrastructure Acceleration
Thank You!