Scalable Electrolytic Systems for Renewable Hydrogen Production

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Overview

Timeline and Budget

• Project start date: 02/26/18
• Project end date: 05/01/19
• Total project budget: $150k
  – Total recipient share: $25k
  – Total federal share: $25k
  – Total DOE funds spent*: $25k

* As of 3/01/19

Barriers

• Utilization of remote off-shore wind resources
• Capital cost reduction

Partners

• GTA
• NREL
• Relevance (H2@Scale CRADA call)
  – Support development of multi-MW (typically 10-12 MW) low temperature water electrolysis system that integrates with off-shore wind farm

• Objectives:
  – Verify technology at TRL4 level
  – Create input for advancement to TRL5 level
Analysis of Electrolyzer-Based Hydrogen Production Costs

• In one H2@scale future scenario 12.8 quad of wind electrical power is added
  (B. Pivovar, DOE FCTO webinar, “H2@scale: Deeply Decarbonizing Our Energy System”, July 28th 2016)
• 12.8 quad = 58 million metric tons H₂/year @ 60% conversion efficiency
• Red square area needed for 12.8 quad/year of electrical power offshore wind energy
• 12.8 quad/year require for example 94,800 wind turbines at 10 MW each; capacity factor = 0.45
### Approach - Technology

**How offshore floating wind farms work**

1. Huge floating wind turbines — each about 600 feet tall — are grouped together and anchored to the ocean floor.
2. Electricity from the turbines is transmitted to a floating substation.
3. The electricity then flows through a buried cable to an onshore power plant.

**Cost of Cable Damage**

- Niels Kragelund - Head of Wind Energy at Danish Insurers Codan says.....
  - "cables account for 90% of the number of offshore wind claims"
  - "cables account for 70% of the actual cost of claims"
- Tim Haiperin-Smith - Director at Global Insurance brokers Willis says ..... 
  - "of all the offshore wind claims his firm receives, most incidents occur during installation, half of them due to human error" 

**High-Voltage Export Cables Cost**

- 25% CAPEX
- 30% of OPEX are cable related liability insurance premiums:
  - 90% legal challenges
  - 70% of those are actual cash settlements

**Wind turbine operating models**

- Electricity single product
- Demand vs. supply challenge
- Typically one customer
- Benefits from value-added H2
Approach - Technology

Fixed Base Turbines

Floating Turbines

- Offshore wind turbine options:
  - Fixed platform
  - Floating spar buoy
- Hydrogen production at wind turbine site
- Minimal electrical power transfer loss from turbine to electrolyzer
- Hydrogen delivery via gas pipelines
Approach - Project

• Project leveraged NREL in-situ testing capabilities
• GTA provided prototype electrolysis cell of ≤700W and other specific laboratory equipment as needed
• NREL integrated and commissioned test equipment
• NREL conducted a series of performance tests
• NREL conducted trace gas analysis on the product hydrogen
• GTA utilized information from exchange into next development step
Accomplishments and Progress

Test setup

• Received, assembled and commissioned at NREL
• Integrated into NREL’s laboratory environment
• Refined with
  – Thermocouple testing
  – Automated performance experiments
  – Automated data collection
  – Backpressure control
Accomplishments and Progress

Verification of Operation

- Electrolyzer performance measured with and without oxygen scrubber
- Performance difference observed between GTA & NREL
  - Assigned to NREL elevation with ambient pressure of 12 psia
  - Bubble size effect expected
  - Only 5 psi gauge pressure operation was available with hardware
- Pressure adjusted to sea level ambient pressures and slightly elevated pressure for fuel quality experiments
Trace Gas Analysis

- Electrolyzer operated with sample cylinder collecting gas samples with and without oxygen scrubber
- Gas analyzed towards SAE J2719 fuels purity standard
- Hydrogen fuel purity reported by GTA verified at NREL
Accomplishments & Progress

Characterization of H₂ purity

- Gas collection with custom containers for Hydrogen fuels purity characterization from Smart Chemistry
- Hydrogen purity as measured = 99.96681%
- H₂O, O₂, and CO₂ as measured are above the stringent SAE J2719 fueling standards
- Gas purity met the expectations and are sufficient for many hydrogen applications for H2@scale objectives
- Simple upgrades could be implemented to meet the SAE J2719 fueling standard
- Removing the H₂O, O₂, and N₂, the hydrogen purity would increase to be above 99.999%
Accomplishments and Progress

TRL4 to TRL5 Transition

• Component validation in relevant environment
• Simulated off-shore operation by submersion of electrolysis stack in seawater
• Redesign of stack for TRL5 demonstration
• Successful operation of submerged system
• Screening test of various diaphragm materials underway
Collaboration and Coordination

• Industry partner: GTA
  – Defined objectives
  – Defined operating conditions
  – Provided information about specific operating procedures
  – Provided specialized equipment
  – Provided data measured at GTA

• National lab partner: NREL
  – Performed system setup in NREL lab for ≤700W cell
  – Performed refinements to experimental setup
  – Confirmed GTA performance
  – Characterized hydrogen quality via trace gas analysis for GTA
Remaining Challenges and Barriers

• Scope of project completed
• No challenges remain within the scope of the project
Proposed Future Work

• Project completed
• No future work planned within this project

• Future work outside this project
  – Demonstrate functionality in various scenarios:
    • Simulated ocean floor pressure submersed in seawater
    • Actual off-shore environment
  – Investigate performance improvement through
    • Pressure operation
    • Electrode optimization
Technology Transfer Activities

- This project did not result in any technology transfer
Responses to Previous Year
Reviewer’s Comments

• Project was not reviewed last year
Summary

• NREL and GTA successfully collaborated on verification and characterization of GTA’s submersible electrolyzer technology for off-shore operation

• Verification of performance data at NREL

• Successful characterization of hydrogen fuels purity
  — Hydrogen purity as measured = 99.97%
  — Theoretical purity above 99.999% after removal of H₂O, O₂, and N₂
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GTA

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NREL

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