MW-Scale PEM-Based Electrolyzers for RES Applications

Cooperative Research and Development Final Report

CRADA Number: CRD-18-00742

NREL Technical Contact: Kevin Harrison

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Contract No. DE-AC36-08GO28308

Technical Report
NREL/TP-5B00-79055
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Cooperative Research and Development Final Report

Report Date: January 27, 2021

In accordance with requirements set forth in the terms of the CRADA agreement, this document is the final CRADA report, including a list of subject inventions, to be forwarded to the DOE Office of Scientific and Technical Information as part of the commitment to the public to demonstrate results of federally funded research.

Parties to the Agreement: Giner ELX (Acquired by PlugPower in 2020)

CRADA Number: CRD-18-00742

CRADA Title: MW-Scale PEM-Based Electrolyzers for RES Applications

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Sponsoring DOE Program Office(s):

USDOE Office of Energy Efficiency and Renewable Energy (EERE), Hydrogen and Fuel Cell Technologies

Joint Work Statement Funding Table Showing DOE Commitment:

Estimated Costs	NREL Shared Resources	Totals
Year 1	$30,000.00	$30,000.00
TOTALS	$30,000.00	$30,000.00

Executive Summary of CRADA Work:

Many nations are rapidly increasing electrical generation capacity from renewable energy sources (RES) such as wind and solar. The wide penetration of RES requires an energy storage solution which has come in the form of hydrogen generated via polymer exchange membrane (PEM) electrolysis. A study of the current state-of-the-art PEM electrolysis indicates that the largest PEM-based stacks range from 150 – 250kW and that a significant scale-up of the technology is required to accommodate multi-Megawatt (MW) energy storage solutions in large-scale RES applications.

Summary of Research Results:

Statement of Work

To address critical aspects for the successful commercialization of Giner ELX's MW PEM-based electrolyzer stacks, three (3) tasks will be performed.

Task 1 the active area of the electrolyzer stack will be scaled-up from 290 centimeters squared (cm^2) (150 kW platform) to 1,250 cm^2 (1 MW platform). In this task Giner ELX will assemble a multi-cell stack based on their 1 MW stack platform having an active area of 1,250 cm^2. The number of cells will be determined based on the power capabilities at NREL's Energy Systems Integration Facility (ESIF) test site. Future scale-up of the 1 MW stack technology to an active area of 3,000 cm^2 (5 MW platform) or greater is feasible.

Results: Task 1 was completed by Giner ELX when the (nominally) 225 kW electrolyzer stack was delivered to NREL in July 2018. The PEM electrolyzer stack has the following capabilities;

- Cell Active Area: 1,250 cm^2
- Stack contains 29 cells, but scalable to 100's depending on hydrogen production required
- Operating Pressure: 40 bar, differential mode
- Operating Temperature: 70°C
- Nominal Operating Current: 3,750A (Current density 3A/cm^2)
- Support stand includes fork-lift access for ease of movement
- CE compliant

Figure 1. 29-cell Allagash electrolyzer stack designed and built by Giner ELX prior to shipment to NREL in July 2018

Task 2 includes integration, and operational testing, of the MW-stack platform at NREL's ESIF facility. The stack will be operated cyclically between a current density of 0 to 3,000 milliampere (mA) mA/cm^2 over a 5,000-hour period. During operation, NREL will monitor individual cell voltage, cross-cell leakage (percentage of hydrogen (H_2) in oxygen (O_2), and collect fluoride samples. The fluoride samples will be delivered to Giner ELX and analyzed to determine membrane/stack lifetimes.

Results: This task was completed by NREL staff when the stack was installed, commissioned and operated to over 4,900 hours. The initial 5,000 hour goal was not fully achieved by the time this CRADA expired, but the lower goal was agreed by email from Monjid Hamdan on September 23, 2019 – well before the CRADA end date in January 2020.

To accomplish this task staff at the Energy Systems Integration Facility (ESIF) completed the following;

- Modified NREL's electrolyzer stack test bed to accommodate 'Allagash' MW-platform stack
- Installed sensors, power cables, pressure regulator, pumps, etc.
- Purchased and installed 2 new (4 total) 250 kW power supplies (AC/DC) to enable stack currents up to 4,000A
    - In current sharing mode, all 4 power supplies will provide the required current (3,750A)
- Test stand is now capable of power up to a 1 MW PEM electrolyzer stack (250V, 4000A)
- **Stack integrated into testbed and all alarms points verified prior to operations which started in August of 2019 – 1 month after delivery**
- A new stainless-steel water tank was designed and installed into the system in August 2019 – replacing the polypropylene tank installed in 2013
- A new cell voltage monitoring system was developed and all cell voltages stable and within range
- As of September 2019, over 2,000 hours was achieved under attended mode of operation and on track to complete operations by end of January 2020
- **Completed over 4,900 hours of stack operations, including a significant portion of hours under un-attended status, by the completion of the CRADA in January 2020**

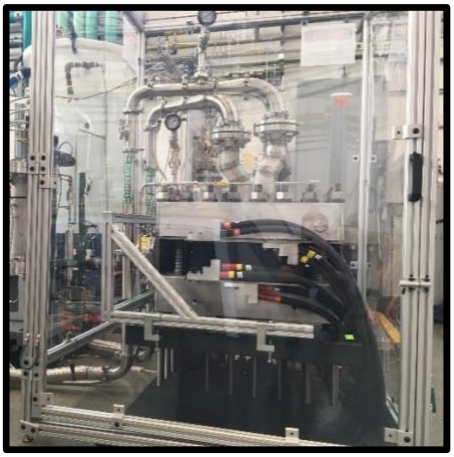

Figure 2. 29-cell Allagash electrolyzer stack fully installed and ready for operations at NREL's ESIF in August 2018

Task 3 Data analysis will be conducted by Giner ELX and NREL to evaluate performance (efficiency, durability, lifetime) of the stack. This includes the effect of the additive on voltage performance and on the stability of the additive during extended operation (5,000 hours) at current densities of 3,000 mA/cm^2. Voltage performance data will also be used to determine the effect on cell components and catalyst utilized in the MW stack platform.

A final report will be prepared as part of Task 3. The final report from Giner ELX and NREL will include a summary of the operational conditions, voltage-current curves as a function of temperature and pressure, fluoride release data, time-series of the stack voltage and histogram/summary tables of hours of stack current levels, cathode pressures and stack temperatures over the 5,000 hours of operation. This operational data will be used to calculate stack voltage efficiency, stack decay rate and predict lifetime based on stack current, fluoride release rates, average stack temperature and anode/cathode pressures.

Results: The results from water sampling to obtain the fluoride release rate, cell voltage, cell decay rate and the amount of hydrogen crossing over to the oxygen side of the stack are presented here. In addition, a representative polarization scan is provided below showing a very small variance on all cells of 30mV with the exception of cells 1 and 29, which were measured on the current collectors and not representative of the actual cell voltage.

- **Fluoride Release Rate measured:** < 6 ppb (3 samples; control 5, 10, and 15 ppb)
    - These results were obtained using water samples from the electrolyzer system and sent out to a laboratory that analyzed for fluoride
- **Low Voltage Degradation rate:** < 1.5 uV per cell – hour after 8,500 hours and <1 µV per cell - hr over 10,000 hour period of 7-cell operation at Giner ELX
- **%H_2 in O_2:** <10% LFL (Water from pressurized H_2 phase separator drains into H_2O/O_2 reservoir
    - These H_2-in-O_2 results were obtained from a combustible gas detector continuously analyzing the presence of hydrogen in a slipstream of oxygen gas being vented from the large de-ionized water tank that acts a gas/water phase separator.

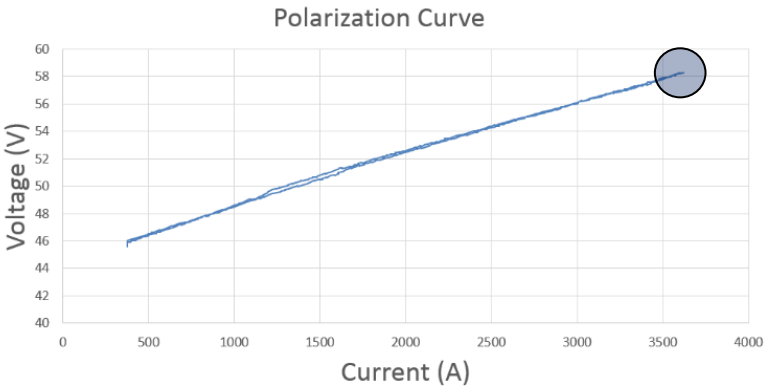

Figure 3. Polarization (voltage-current) scan showing < 2 V per cell in the shaded circle at maximum current density of 3A/cm^2

Figure 3 highlighting the PEM stack voltage of 58.1 V (< 2 V per cell) at full stack current 3,750A while holding cathode pressure at 40 bar and average stack temperature of 70°C.

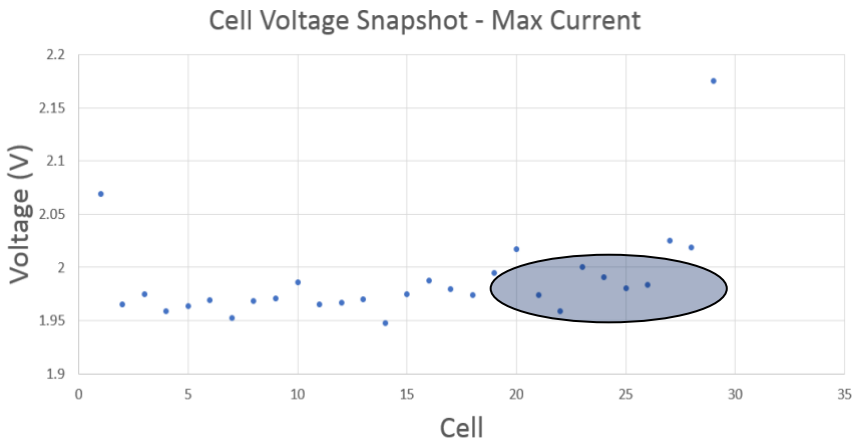

Figure 4. Snapshot of cell voltages at 3,750A with high anode water flow showing the shaded cells running cooler (t = 300 hours).

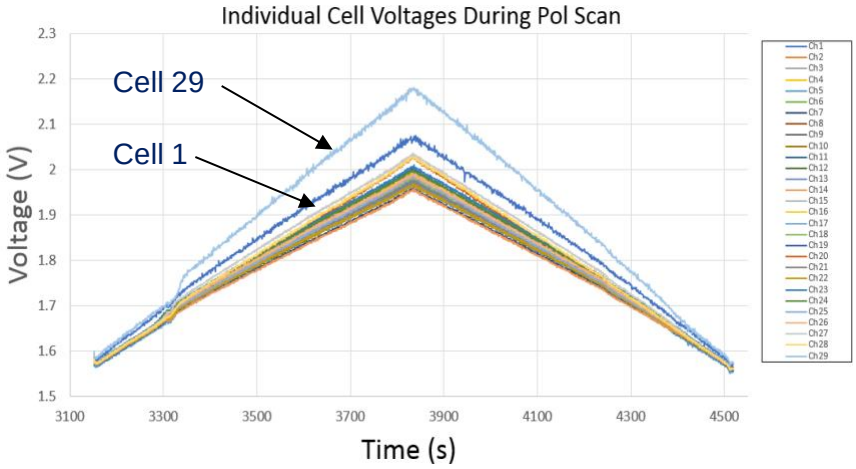

Figure 5. Approximately 30mV variance of cell voltages at 3A/cm^2 with exception of end cells (1 and 29) being measured on the current collectors during a polarization scan

Error! Reference source not found. is a graph of all 29 cell voltages versus time during a polarization scan. Excluding cells 1 and 29, due to their sense location on the large plates where power wiring is connected (i.e., the current collectors), shows a very tight distribution of cell voltages being less than 30 mV at full current density of 3A/cm^2.

Summary Conclusion:

This is the final report required in Task 3 with details of the work described in Tasks 1 – 3. Under this CRADA Giner ELX designed, built and delivered a 29-cell electrolyzer stack to NREL in July 2018. NREL completed upgrades to the balance of plant and installed the 225 kW electrolyzer stack in August 2018. Roughly 2,000 hours of attended operation were accumulated within the next year before NREL was able to receive approval to run unattended 24/7. Over 4,900 hours of operation were completed by the CRADA end date in January 2020.

During this time water samples were captured at NREL, shipped to Giner ELX where an outside lab performed analysis for fluoride that provides insight into how much the cells are degrading over time. Electrolyzer stack test bed was continuously monitored for water flow, cathode

pressure, average stack temperature and hydrogen cross-over to the anode side of the stack. Periodically, NREL performed polarization scans, while maintaining cathode pressure and stack temperature, where stack current was varied from roughly 375A up to 3,750A while monitoring stack and cell voltages. The polarization scans, also called voltage-current scans, provide further insight on how cell/stack voltages are performing over the full range of stack power.

Subject Inventions Listing:

None

ROI #:

None