VII.5 Validation of an Advanced High-Pressure PEM Electrolyzer and Composite Hydrogen Storage, With Station Operating Data Reporting, at the SunHydro Stations

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SunHydro LLC, CT

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Project End Date: November 30, 2013
(Go/No-Go decision for next phase)

Overall Objectives

- Validate energy savings of up to 11 kWh/kg H_2 through system and stack advancements
- Double usable hydrogen storage per unit volume by increasing pressure cycling range
- Provide advanced packaging design to reduce station footprint
- Collect and report station performance for up to 24 months

Fiscal Year (FY) 2013 Objectives

- Build full-scale advanced cell stack for stack portion of energy savings
- Install system upgrades for reduced dryer losses for system portion of energy savings
- Complete analysis of codes and standards for advanced packaging arrangement
- Complete instrumentation of station and initiate reporting of station performance

Technical Barriers

This project addresses the following technical barriers from the Technology Validation section of the Fuel Cell Technologies Office Multi-Year Research, Development, and Demonstration Plan:

(C) Hydrogen Storage

(D) Lack of Hydrogen Refueling Infrastructure Performance and Availability Data

(E) Codes and Standards

Technical Targets

Advanced Electrolysis-Based Fueling Systems: There is not a specific target table in the Technology Validation section of the Multi-Year Research, Development, and Demonstration Plan specific to hydrogen refueling infrastructure. This project is conducting technology validation of improved cell stack, system, and storage components for an electrolysis-based hydrogen refueling station. These improvements will support the following targets:

- Reduce station energy use by up to 11 kWh/kg
- Reduce the storage volume by 50% per kg of hydrogen dispensed
- Package a station based on proton exchange membrane (PEM) electrolysis within a 12-meter International Organization for Standardization (ISO) container

FY 2013 Accomplishments

- Procured new tooling for the high-efficiency electrolyzer cell stack and ordered long-lead system and stack parts
- Finalized system design approach for 55-bar upgrade
- Built test system for high-efficiency cell stack, to be modified for 55-bar operation
- Reviewed safety codes and zoning standards for compact component arrangements
- Completed design review with Air Products for storage upgrades
- Ordered Type II extended pressure cycle range storage tubes and ancillaries
- Ordered major fueling system components for compact station arrangement

INTRODUCTION

This project primarily leverages Proton's SunHydro#1 station in Wallingford CT, with access to over 100 kg/day in generation capacity, and a new containerized SunHydro#2 station deploying to Braintree, MA, for technology validation of improved components for hydrogen fueling stations (Figure 1). Since its grand opening in 2010, SunHydro#1 has generated and dispensed in excess of 5,800 kg of hydrogen over thousands of fueling events. Our compact, containerized SunHydro™ station design embodied by SunHydro#2 can address initial demand for small, manufactured H_2 fueling infrastructure in a manner that affords rapid, scalable deployment. The SunHydro station product 'skid', integrating H_2 generation, compression, storage, and dispensing in an intermodal transport ISO container, mitigates significant site permitting issues by virtue of its small 40' x 8' footprint and an innovative application of hydrogen code that drastically reduces required clearances.

Proton and SunHydro LLC are ready to continue down this pathway to demonstrate advanced generation/compression/storage component technologies, including 1) higher pressure hydrogen generation with electrochemical compression, 2) higher efficiency generation with lower resistance electrolyte and advanced catalyst, 3) higher addressable capacity composite storage, and 4) advanced packaging concepts for reduced footprint. Testing will be performed on the compression and drying efficiency as part of the higher generation pressure improvement. The station will also be monitored quarterly for hydrogen produced, stored, and dispensed as well as for the resulting energy consumption by major station subcomponents.

APPROACH

These hydrogen fueling improvements will be accomplished based on the following approaches. For higher pressure/higher efficiency PEM cell stacks, Proton has recently qualified a 30% reduction in PEM membrane thickness for 15- and 30-bar hydrogen generator product lines. The thinner material has been fully qualified with over 5,000 hours of continuous operation in a commercial-scale cell stack and is now ready for introduction to the fueling scale product line, to be operated at 55 bar. Furthermore, Proton has been developing advanced catalyst materials and processes that simultaneously reduce the cost of the product and improve the electrochemical performance. Ongoing work on Proton's Phase II Small Business Innovative Research project through the Department of Energy has been successful in developing an alternate catalyst application technique resulting in 50% less catalyst usage as well as efficiency gains due to the lower ohmic resistance. This change is going through production release at the smaller scale commercial stack level. Through this technology validation effort, the tooling is also being procured for the larger size for phase-in after the initial production qualification. A 55-bar militarized cell stack design will be built using the thinner material and advanced catalyst

FIGURE 1. SunHydro#1 and SunHydro#2 Stations

deposition to show the performance improvement at full scale compared to previous technology stacks. A 55-bar capable balance-of-plant system that can accept multiple 55-bar cell stacks is required to validate these improvements at fueling station scale. We will upgrade a commercial 30-bar C series electrolyzer's hydrogen-water management system to operate at 55 bar by strengthening the gas drying components. An increase in hydrogen generation pressure from 30 bar to 55 bar can improve hydrogen fueling system efficiency in two areas – H2 gas drying and dried H2 compression into station storage. With increased H2 generation pressure the relative fraction of water present in the gas decreases, positively impacting the performance of the hydrogen gas dryer since it has less water vapor to remove. As a result of the lower water concentration, the dryer purge losses can be expected to decrease substantially since the water vapor concentration at 55 bar will be about 55% of the concentration at 30 bar. Higher dry H2 pressure into the station mechanical compressor will result in better combined compression energy and higher throughput capability.

For higher addressable capacity storage and reduced station footprint, Proton will install and validate new compact Type II composite storage tubes and apply fresh interpretations of hydrogen safety code to design a complete fueling station within the compact footprint of an ISO container. Proton will apply these new rules to the design of SunHydro#2 station.

The impact of all performance improvements will be reported through instrumentation of the station before and after the design changes. The impact of new compact station arrangements will be reported in site approval time and in station operability data.

RESULTS

As this project is technology validation, most results of cell stack and system technology performance will be reported after technology deployment and test scheduled for late FY 2013 and FY 2014.

The build of the Proton C Series 30 hydrogen generator that will act as the test bed for the advanced cell stack was completed in late 2012. This system completed its verification testing and is currently supplying the hydrogen used by the Sun Hydro#1 station at Proton. The hydrogen gas management portion of the commercial C series 30 bar pressure hydrogen generator is comprised primarily of proprietary design hydrogen/water phase separator and a pressure swing absorber. Proton engineering completed a mechanical design analysis of these components to learn that only minor changes to valve seats, retaining bolts, and pressure sensors are needed to operate at 55 bar. This allows Proton to proceed with the modifications.

Modifications to model code that can affect containerized hydrogen solutions were discussed during a first draft revision working meeting of the National Fire Protection Association (NFPA) 2 Hydrogen Technology Code committee in June 2013 on which Proton is a member. Hydrogen infrastructure stakeholders in attendance – industry, enforcement authorities, code developers, national labs, vehicle manufacturers – recognized a code gap concerning larger containerized hydrogen solutions for storage, energy production, and fueling systems. Containerization is being implemented as a means to reduce site requirements and approval time for hydrogen infrastructure. Existing model code treats shipping containers as a building, which can impose additional equipment, site, and clearance requirements not typically required of industrial equipment that can limit enforcer latitude in approving containerized systems, especially when in close proximity to existing buildings and occupancies. Clear and specific code language addressing containerized equipment as equipment can serve to help the code enforcer accelerate approvals. At the meeting an outline of new code language was put forth by membership and a working subcommittee formed with Proton as chair to develop the language favorable to providing code enforcers appropriate guidance when considering containerized systems. This work will aid approval and deployment of SunHydro#2 station in a 12-meter ISO container. Initial meetings with authorities in Braintree, MA, the site of SunHydro#2, have been very favorable already due to local zoning laws that regard a shipping container footprint as needing very little consideration in terms of setbacks and other building site constraints.

Work on a compact fueling station arrangement for the SunHydro#2 station has advanced to where major components are on order. Typical fueling station arrangements use explosion-proof equipment and housings to contain electrical power and controls. This approach limits accessibility for service and maintenance. Typical model code application forces significant separation distances from high pressure storage to personnel, adjacent buildings, and equipment, on the order of 25 to 35 feet. These tend to drive up station material and build costs and increase station footprint beyond acceptable limits. Proton has developed fueling-class water electrolyzers that, due to their minimal hydrogen content, do not require or introduce hazardous location classification on their own. Our analysis of compact hydrogen station component arrangements under this work shows an advantage to using the non-classified area immediately around our PEM hydrogen generator to house almost all electrical power and control equipment. Further, the NFPA 2 hydrogen code permits reduction of separation distances from hydrogen storage to electrical exposures and unclassified areas to be reduced to near zero when a 2-hour rated firewall is interposed. Proton has identified relatively inexpensive materials and construction that can be used to compactly create a 2-hour firewall in between two containers or to demise one container. Our arrangement analysis to date shows significant space saving advantages in placing this firewall in between the non-classified electrolyzer generator container space and the classified container space housing compression, storage, and a built-in dispenser. Ancillary cooling equipment may be placed on the roof of the non-classified H2 generation container section, with a firewall interposed line-of-site to the classified compression, storage, and a built-in dispenser (Figure 2). This approach will be validated to meet the 8' x 40' goal in the SunHydro#2 station under construction as of this report.

CONCLUSIONS AND FUTURE DIRECTIONS

- Conclusions to date:
  - Modeling of component arrangements aided by application of up-to-date model code show that a full-size hydrogen fueling station can be implemented within a 8'x 40' container space and incorporate PEM H2 generation, H2 compression, storage, and dispensing with cooling ancillary components mounted on the roof.
- Future directions:
  - An advanced full-size 55-bar PEM cell stack will be built and tested along previous designs to validate higher pressure and efficiencies improve station efficiency by up to 11 kwh/kg H2
  - Higher addressable storage tanks will be installed and validated in two stations
  - A compact containerized fueling station will be deployed and permitted
  - Both stations will be instrumented to facilitate reporting of station performance.

FY 2013 PUBLICATIONS/PRESENTATIONS

1. AMR 2013 moulthrop, TV012

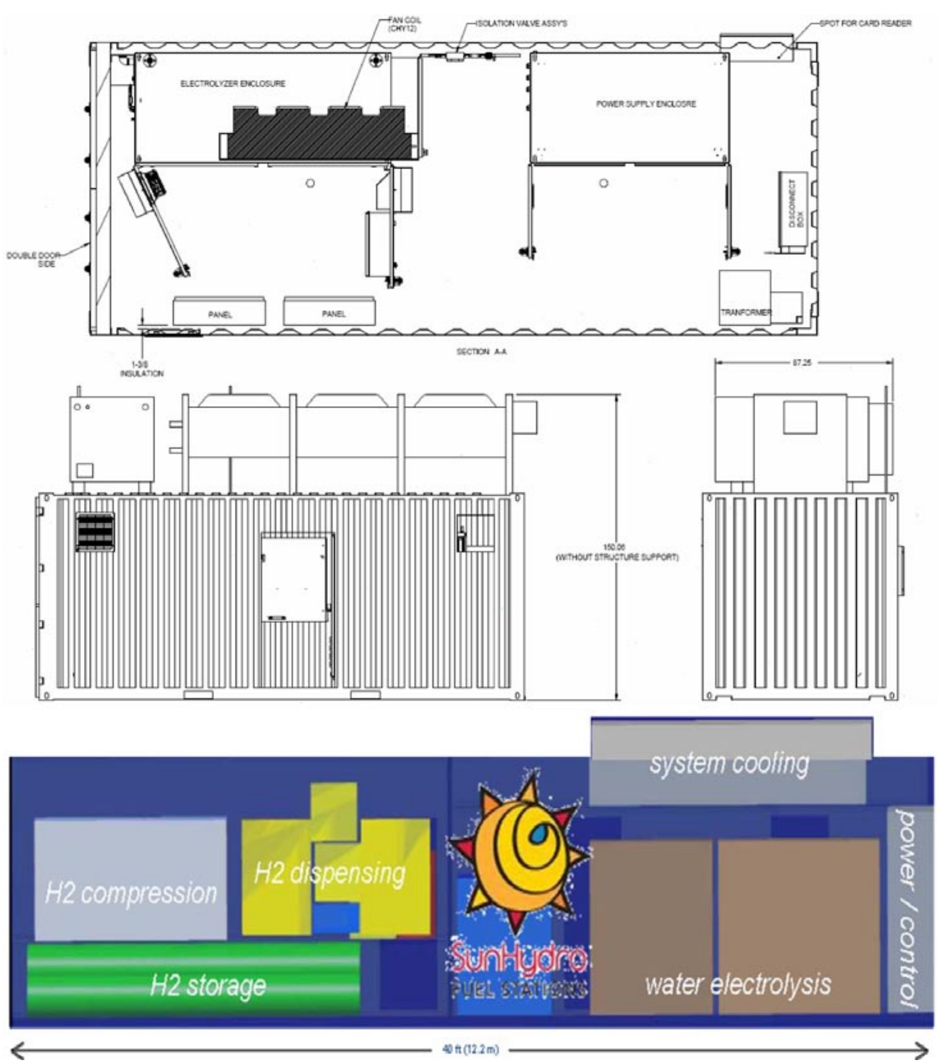

FIGURE 2. Arrangement, H2 Generator Container Section and SunHydro Concept