X.1 Hydrogen Energy Systems as a Grid Management Tool

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Project Start Date: September 30, 2010
Project End Date: September 29, 2015

Overall Objectives

- Demonstrate the use of electrolyzers to mitigate the impacts of intermittent renewable energy by regulating grid frequency.
- Characterize performance/durability of commercially available electrolyzers under dynamic load conditions.
- Supply hydrogen to fuel cell shuttle buses operated by County of Hawaii Mass Transit Agency and Hawaii Volcanoes National Park (HAVO).
- Conduct performance and cost analysis to identify benefits of an integrated system including grid ancillary services and off-grid revenue streams.
- Evaluate effect on reducing overall hydrogen costs offset by value-added revenue streams.

Fiscal Year (FY) 2016 Objectives

- Conduct a hydrogen site safety review utilizing an independent third-party consultant.
- Install site improvements and utilities at Natural Energy Laboratory Hawaii Authority (NELHA) to support the operation of the hydrogen system.
- Install, commission, and operate the hydrogen system at NELHA.
- Install a 350-bar hydrogen fuel dispenser at NELHA to fuel the Mass Transit Agency fuel cell electric shuttle bus.
- Characterize performance and durability of the electrolyzer system under dynamic load conditions at Powertech Labs facilities in Vancouver, Canada, prior to shipping equipment to Hawaii.
- Conduct performance and cost analysis to identify benefits of integrated systems including grid services and off-grid revenue streams.

Technical Barriers

This project addresses the following technical barriers from the Market Transformation section of the Fuel Cell Technologies Office Multi-Year Research, Development, and Demonstration Plan.

(A) Inadequate standards and complex and expensive permitting procedures

(B) High hydrogen fuel infrastructure capital costs for Polymer Electrolyte Membrane (PEM) fuel cell applications

(C) Inadequate private sector resources available for infrastructure development

(F) Inadequate user experience for many hydrogen and fuel cell applications

(G) Lack of knowledge regarding the use of hydrogen inhibits siting (e.g., indoor refueling)

(H) Utility and other key industry stakeholders lack awareness of potential renewable hydrogen storage application

Technical Targets

No specific technical targets have been set.

FY 2016 Accomplishments

- Conducted workshop utilizing Boyd Hydrogen for County of Hawaii planning, permitting, and fire department leadership on National Fire Protection Association (NFPA)-2 hydrogen codes and standards in order to facilitate permitting.
- Awarded contract for the installation of site improvements and utilities at NELHA to support the operation of the hydrogen system.
- Secured additional funding from the State of Hawaii to support site improvements.

- Conducted second factory acceptance trial at Powertech Labs.
- Modified electrolyzer control system to improve response time.
- Conducted three months of testing and analysis at Powertech Labs supervised by onsite HNEI staff.

INTRODUCTION

While solar and wind resources offer a major opportunity for supplying energy for electrical grid electricity production and delivery systems, their variability and intermittency can raise challenges for the cost-effective and high-reliability integration of these renewable sources on electrical grids. In Hawaii, the curtailment and grid management related challenges experienced by these renewable sources are a challenge at today's level of generation capacity, and these costs will hinder the substantive additional penetration of electricity generation supplied by these renewable resources. Hydrogen production through electrolysis may provide an opportunity to mitigate curtailment and grid management costs by serving as a controllable load allowing real-time control in response to changes in electricity production. The renewable hydrogen product can also create new and incremental revenue streams to the power producers through the sale of hydrogen products to customers outside of the electricity delivery system. Accordingly, hydrogen energy production at a utility scale offers the potential for increasing the levels of variable renewable energy that can be harnessed by the power producers or systems operators.

APPROACH

This project evaluates the value proposition of using utility-scale electrolyzers to both regulate the grid and use the product hydrogen for transportation applications. An electrolyzer system is being installed at NELHA on the Big Island. The electrolyzer will be ramped up and down to provide frequency regulation. Data will be collected to analyze the optimum electrolyzer ramp rates and determine its durability and performance under dynamic operating conditions over time. The hydrogen produced by the system will be used to fuel three hydrogen-fueled buses. It is planned to deliver hydrogen to HAVO as per the original plan to support two HAVO buses. The third bus will be operated in Kailua-Kona. A schematic of the project concept is shown in Figure 1.

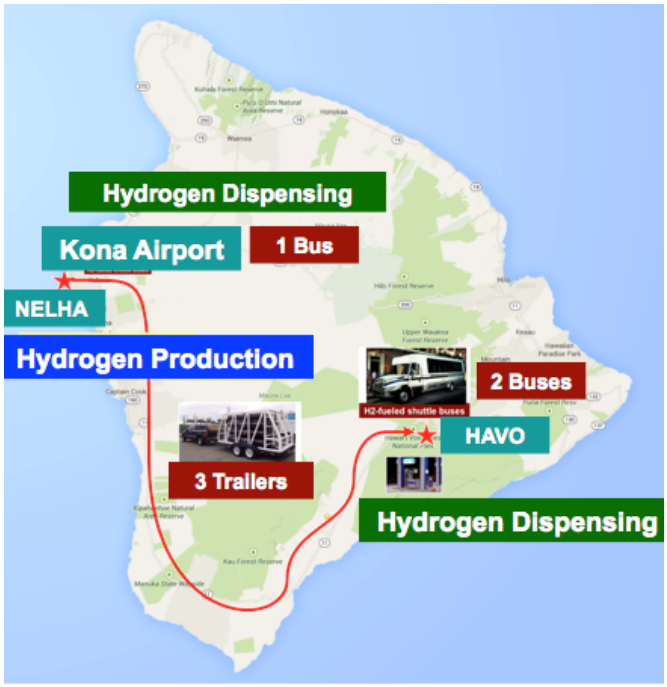

FIGURE 1. Hydrogen production and delivery system

RESULTS

A revised infrastructure design was developed and reviewed by a third-party hydrogen safety consultant (Boyd Hydrogen). A site improvement bid package was prepared and issued for public tender, and a contract was awarded in June 2016. In parallel to the site work, HNEI ran cycling tests on the electrolyzer system utilizing test protocols based on operational data collected from a 1 MW battery energy storage system (BESS) installed on the Hawaii Electric Light Company grid for frequency regulation. An HNEI-designed programmable logic controller and power monitoring system was used for control of the electrolyzer system to facilitate implementation of the electrolyzer testing protocols and support data collection. A second factory acceptance trial was conducted at Powertech Labs facilities in Vancouver, Canada, in February 2016 to validate technical modifications that were made by Powertech to address technical issues identified during the commissioning phase. HNEI staff modified and tested the electrolyzer control system. The control system modifications improved the reaction time of the electrolyzer by a factor of ten and demonstrated the potential of the electrolyzer to provide grid frequency support.

CONCLUSIONS AND FUTURE DIRECTIONS

This project has coordinated the efforts of a diverse group of stakeholders to provide a technology solution to facilitate integration of intermittent renewable energy

sources on an electrical grid while producing hydrogen for transportation. The project has identified and provided valuable solutions to the many non-technical barriers associated with introducing hydrogen technology into a community for the first time. Lessons learned from this project will make the way easier for projects that follow.

It is concluded that a hydrogen energy system is a valuable grid frequency management tool capable of controlling intermittent renewable sources of energy for grid frequency management applications. While the hydrogen energy system is not as fast as the BESS, the performance measured with the modified control system under different load demands is much closer to the BESS performance. However, our current thinking is that replicating the exact operational response time as the BESS cannot be achieved with an electrolyzer. The data show that the electrolyzer can only be used for slower acting changes (1 Hz to 0.5 Hz). A potential solution is to design an electrolyzer–BESS hybrid system and develop a modeling program to find the optimum mix of battery and electrolyzer to provide the maximum grid regulation services at minimum cost. Additional work is required to develop a control scheme that can manage power distribution between the electrolyzer and BESS.

While DOE participation in the project formally ended on September 30, 2015, the project will continue using other funding. Future work involves the following:

- Completing installation, and operating hydrogen production systems and dispensing infrastructure at the NELHA site.
- Operating the 26-passenger fuel cell electric bus based at the NELHA site.
- Transporting hydrogen in hydrogen transport trailers from the NELHA production site to the HAVO dispenser to support the two park service fuel cell electric buses.
- Collecting and analyzing hydrogen system and fuel cell electric bus performance data.
- Preparing performance reports and sharing them with project sponsors and industry.
- Conducting outreach activities with the public to inform them about hydrogen technologies.

FY 2016 PUBLICATIONS/PRESENTATIONS

1. Ewan, M., Rocheleau, R., Oral presentation at U.S. Department of Energy Hydrogen and Fuel Cells Program Annual Merit Review, "Hydrogen Energy Systems as a Grid Management Tool," Washington, D.C., June 9, 2016.