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/cost analysis to identify the 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) 2017 Objectives

- 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 County of Hawaii Mass Transit Agency fuel cell electric shuttle bus.
- Install a 350-bar hydrogen fuel dispenser at HAVO to fuel two HAVO shuttle buses.
- Develop a HAVO compressor boost system to extract up to 90% of the hydrogen from the hydrogen transport trailers and reduce hydrogen transport cost by 50%.

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 2017 Accomplishments

- Obtained permits from the County of Hawaii for the installation of site infrastructure at NELHA.
- Commenced installation of site improvements and utilities at NELHA to support the operation of the hydrogen system.
- Delivered the hydrogen system equipment to the NELHA site.
- Completed the conversion of the County of Hawaii Mass Transit Agency bus.
- Completed the conversion of the HAVO buses, including installation of a novel environmental sensor system for the air filtration system to protect their fuel cells from high levels of air contamination experienced in the park.

- Executed a memorandum of agreement with HAVO for the siting and operation of the hydrogen system at HAVO.
- Completed the HAVO compressor boost system.
- Completed modifications to the three hydrogen transport trailers to interface with the HAVO hydrogen boost system.
- Commenced the development of a dynamic model of the hydrogen production system.

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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 system operators.

APPROACH

This project evaluates the value proposition of using 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 simulate 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 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

This was the first hydrogen project evaluated by the County of Hawaii Planning Department. Several revisions to the NELHA infrastructure design were developed and reviewed by a third party hydrogen safety consultant (Boyd Hydrogen). The permitting package was approved in June 2017. Work was started on the site improvements, and the hydrogen system equipment was shipped and delivered to the site (Figures 2 and 3). In parallel, work was completed on the conversion of the three hydrogen buses, including installation of a novel fuel cell air filtration Environmental Sensor Array system designed to protect the two HAVO buses' fuel cells from high levels of volcanic sulfurous air contaminants experienced in the park. The delivery of hydrogen to HAVO will be accomplished via three hydrogen transport trailers using a drag-and-drop strategy. Using a cascade fill would result in the trailers being able to dispense only ~50% of their contents. Given the high cost of transportation, it was decided to develop a compressor system that could extract more hydrogen from the trailer. This was accomplished through the development of a compressor boost system (Figure 4), which will allow ~90% of the hydrogen to be dispensed, resulting in a reduction of hydrogen transport costs of ~50%. Work also started on the development of a hydrogen energy system simulation tool that includes models for different renewable power sources, the utility grid, electrolyzer, battery energy storage system, and system control algorithms. The overall structure has been developed in MATLAB and Simulink. A steady state model of a PEM electrolyzer has been created

FIGURE 2. NELHA site infrastructure

FIGURE 3. Delivery of hydrogen system equipment

FIGURE 4. Compressor boost system

and validated with measured data from the project Proton C30 electrolyzer. The electrolyzer steady state model has been implemented in the MATLAB and Simulink environment, where the dynamic characteristics and control of the electrolyzer system will be implemented.

CONCLUSIONS AND UPCOMING ACTIVITIES

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 battery energy storage system (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 shows 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 the U.S. Department of Energy participation in the project formally ended on September 30, 2015, the project is being continued 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 HAVO buses;
- Collecting and analyzing hydrogen system and fuel cell electric vehicle bus performance data;
- Preparing performance reports and sharing it with project sponsors and industry; and
- Conducting outreach activities with the public to inform them about hydrogen technologies.

SPECIAL RECOGNITIONS & AWARDS/ PATENTS ISSUED

1. A utility patent application was submitted for the Environmental Sensor Array system.

FY 2017 PUBLICATIONS/PRESENTATIONS

1. Ewan, M., Rocheleau, R., Oral presentation at U.S. Department of Energy Annual Merit Review, “Hydrogen Energy Systems as a Grid Management Tool,” Washington, DC, June 7, 2017.

2. Ewan, M., Oral presentation at the Natural Energy Laboratory Hawaii Authority “Conference on Energy Storage Trends and Opportunities,” “Hydrogen Energy Systems as a Grid Management Tool,” Kailua-Kona, HI, September 13, 2016.

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