Hydrogen Energy Systems as a Grid Management Tool

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Contract Number: DE-EE0002811

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 and durability of commercially available electrolyzers under dynamic load conditions.
- Supply hydrogen to fuel cell shuttle buses operated by County of Hawaii Mass Transit Agency (MTA) and Hawaii Volcanoes National Park (HAVO).
- Conduct performance and cost analysis to identify benefits of 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) 2018 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 MTA fuel cell electric vehicle (FCEV) 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%.
- Recertify three hydrogen transport trailers to extend operations for another 5 years.
- Complete the conversion of the MTA bus and install an export power unit to supply 110/220 VAC power for civil defense emergency power.

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[1]:

(A) Inadequate Standards and Complex and Expensive Permitting Procedures

(B) High Hydrogen Infrastructure Capital Costs

(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

(H) Utility and Other Stakeholders Lack Awareness of Potential Hydrogen Production and Storage Applications.

[1] https://www.energy.gov/eere/fuelcells/downloads/fuel-cell-technologies-office-multi-year-research-development-and-22

Technical Targets

No specific technical targets have been set.

FY 2018 Accomplishments

- Completed installation of site improvements and utilities at NELHA to support the operation of the hydrogen system.
- Installed 350-bar hydrogen fuel dispenser at NELHA to fuel the MTA FCEV bus.
- Completed the conversion of the MTA bus and installed the 110/220 VAC export power unit.
- Replaced the original MTA bus 30 kW fuel cell power system with a new technology US Hybrid 40 kW fuel cell power system.
- Completed recertification of three hydrogen transport trailers.
- Completed the development of a dynamic simulation model of the hydrogen production system.
- Completed the development of the HAVO compressor boost system.

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 will hinder the substantive additional penetration of electricity generation supplied by these renewable resources. We believe 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 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 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 concept

RESULTS

Considerable progress was made in FY 2018. With the permitting approved in FY 2017, the site improvements and installation of the hydrogen system equipment (Figures 2, 3, and 4) were completed in May 2018.

Figure 2. NELHA site infrastructure

Figure 3. Entrance to NELHA hydrogen site

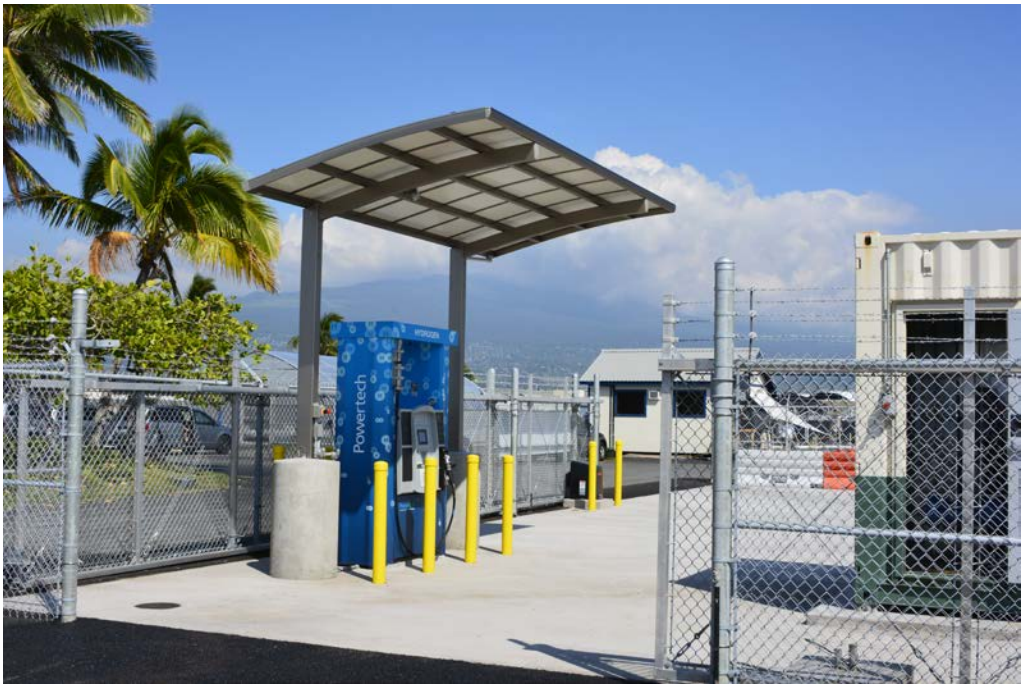

Figure 4. NELHA 350-bar dispenser

This was followed by commissioning the electrolyzer and compressor systems by their respective suppliers/ manufacturers. The recertification of the hydrogen transport trailers (HTTs) was completed by Luxfer, the cylinder manufacturer; however, the requirement to install an upgraded design of the thermal pressure relief devices resulted in a significant additional expense and delays in obtaining the new devices, and it has delayed shipping the units to Hawaii. This also impacted the completion of the final commissioning of the overall system by several months because the HTTs are a significant component of our infrastructure design. In parallel, work was completed on the conversion of the three hydrogen buses including installation of a new technology 40 kW US Hybrid fuel cell on the MTA bus. The MTA bus was also retrofitted with a US Hybrid power export unit that converts the stored energy on the bus to 110/220 VAC power for up to 30 hours. The bus can then be refueled with hydrogen for another 30 hours of power. This effectively converts the bus into a mobile power supply that supports civil defense during environmental emergencies such as hurricanes. The delivery of hydrogen to HAVO will be accomplished via the 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, which will allow ~90% of the hydrogen being dispensed, resulting in a reduction of hydrogen transport costs of ~50%. The boost compressor system has been completed but cannot be shipped until it has completed testing with each of the hydrogen transport trailers. In May 2018 Mother Nature struck a major blow to the project with the eruption of the Kilauea volcano at HAVO, causing significant damage to HAVO's infrastructure. After 3 months, the eruption finally stopped in August; however, volcanologists have stated there is no guarantee that the eruption will not start again. The HAVO segment of the project is currently on hold until the situation has been clarified.

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 (HES) is a valuable grid frequency management tool capable of controlling intermittent renewable sources of energy for grid frequency management applications. While the HES 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 DOE participation in the project formally ended in 2015, the project is being continued using other funding. Future work involves following:

- Operating hydrogen production systems and dispensing infrastructure at the NELHA site
- Operating the 29-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 FCEV 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 2018 PUBLICATIONS/PRESENTATIONS

1. M. Ewan and R. Rocheleau, “Hydrogen Energy Systems as a Grid Management Tool,” Oral presentation at the DOE Hydrogen and Fuel Cells Program Annual Merit Review, Washington, DC, June 14, 2018.
2. M. Ewan, “Supporting a Hawaii Hydrogen Economy,” Oral presentation at First International Hydrogen Forum, San Jose, Costa Rica, August 13, 2018.