IX.4 Hydrogen Energy Systems as a Grid Management Tool

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Project Start Date: September 30, 2010
Project End Date: September 29, 2013

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 (MTA), and Hawaii Volcanoes National Park
- Conduct performance/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) 2013 Objectives

- Contract the Hawaii Center for Advanced Transportation Technologies to convert the El Dorado bus to a fuel cell electric vehicle (FCEV) utilizing a Hydrogenics fuel cell power system
- Finalize Puna Geothermal Ventures (PGV) agreement
- Develop a project hydrogen safety plan
- Engage the DOE Hydrogen Safety Panel to support hydrogen safety including equipment installation, project hydrogen safety plans, outreach to the authorities having jurisdiction, and first responder training
- Respond to questions posed by the public on the draft Environmental Assessment (EA) for the installation of a hydrogen system at the PGV power plant on the Island of Hawaii prepared in FY 2012 and complete the final draft of the EA
- Install site improvements and utilities at the PGV geothermal plant to support the operation of the hydrogen system
- Hire a contractor to operate and maintain the hydrogen system
- Install, commission, and operate the hydrogen system at PGV
- Procure two Powertech 450-bar tube trailers to transport hydrogen from PGV to the County of Hawaii MTA bus yard in the town of Hilo, and Hawaii Volcanoes National Park
- Purchase a Ford F-450 diesel truck to tow the tube trailer
- Install a 350-bar hydrogen fuel dispenser at the MTA base yard in Hilo
- Purchase an El Dorado 2012 ENC AeroElite 290, 19-seat shuttle bus
- Supply hydrogen for a FCEV shuttle bus for local community bus service operated by the County of Hawaii MTA
- Characterize performance/durability of the Proton polymer electrolyte membrane electrolyzer under dynamic load conditions
- Conduct performance/cost analysis to identify benefits of integrated systems including grid services and off-grid revenue streams

Technical Barriers

This project addresses non-technical issues that prevent full commercialization of fuel cells and hydrogen infrastructure as indicated in the following sections of the July 2013 amendments to the Fuel Cell Technologies Office Multi-Year Research, Development and Demonstration Plan:

Section 3.1.5 - Hydrogen Production Technical Barriers

(J) Renewable Electricity Generation Integration (for central)

(K) Manufacturing

(M) Control & Safety

Section 3.2.5 - Hydrogen Delivery Technical Barriers

(E) Gaseous Hydrogen Storage and Tube Trailer Delivery Costs

(K) Safety, Codes, and Standards

Section 3.3.5 - Hydrogen Storage Technical Barriers

(B) System Cost

(C) Efficiency

(F) Codes & Standards

(H) Balance-of-Plant (BOP) Components

(I) Dispensing Technology

Section 3.7.5 - Hydrogen Safety, Codes, & Standards

(B) Availability and Affordability of Insurance

(D) Lack of Hydrogen Knowledge by Authorities Having Jurisdiction

Section 3.8.5 – Education and Outreach Technical Barriers

(D) Lack of Educated Trainers and Training Opportunities

Section 3.9.5 – Market Transformation Barriers

(A) Inadequate Standards and Complex & Expensive Permitting Procedures

(B) High Hydrogen Infrastructure Capital Costs for Polymer Electrolyte Membrane (PEM) Fuel Cell Applications

(C) Inadequate Private Sector Resources Available for Infrastructure Development

(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

(J) Insufficient Numbers of Trained and Experienced Servicing Personnel

(K) Inadequate Installation Expertise

(L) Lack of Qualified Technicians for Maintenance

(M Lack of Certified Service Providing Organizations for Installation and Maintenance

FY 2013 Accomplishments

- Completed site designs for installation of equipment at PGV and MTA sites
- Prepared a draft EA and made an initial "Finding of No Significant Impact"
- Published "Finding of No Significant Impact" on the internet and presented project to the local community
- Prepared draft responses to public comments
- Prepared a draft operations and maintenance contract to support daily operation of the hydrogen systems
- Developed a draft Memorandum of Agreement with MTA
- Engaged DOE Hydrogen Safety Team to support hydrogen safety
- Conducted First Responder Training to over 150 County of Hawaii firefighters utilizing the Pacific Northwest National Laboratory training program
- Completed a "Factory Acceptance Trial" of the Powertech hydrogen system equipment and control systems comprised of:
  - Autonomous data acquisition, monitoring and control system
  - Hydrogen production and compression module
  - Hydrogen transport trailer
  - Hydrogen dispensing system
- Continued to work with PGV to progress Memorandum of Agreement

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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 systems operators.

APPROACH

A four-step process is required to evolve island energy systems:

- Develop and validate rigorous analytic models for electricity and transportation.
- Develop and model scenarios for the deployment of new energy systems including additional renewables.
- Identify and analyze mitigating technologies (demand side management, storage, smart grid, advanced controls, forecasting, future gen) to address systems integration (grid stability) and institutional issues.
- Conduct testing and evaluation to validate potential solutions to facilitate utility acceptance.

Under separate and ongoing DOE and industry-funded efforts, HNEI has been conducting energy roadmapping and technology validation to identify economically viable technologies to transform island energy infrastructures. A full network model incorporating generator governors and automatic generator control was developed that provided the following capabilities:

- Transient stability simulation looks at challenging times with fluctuating renewables to check transient stabilities.
- Long-term dynamic simulation.

A production cost model was developed that provided the following capabilities:

- Representation of dispatch and unit commitment rules
- Hour-by-hour simulation of grid operations for a full year taking into account ramp rates and dispatch rules—for example minimum percentage load for baseload units.
- Yields cumulative fuel usage, emissions, and variable costs.

Frequency variability due to wind fluctuation of the Big Island grid was used as the initial test of the models. The Big Island grid has the following characteristics:

- 100 to 200 MW with early evening peak
- 30 MW wind
- 38 MW regulated geothermal
- Significant and growing photovoltaics

To explore the potential of the hydrogen production opportunity, this project will evaluate the value proposition of using utility-scale electrolyzers to both regulate the grid and use excess electricity from renewables to make hydrogen for various products. In this initial phase of the project, an electrolyzer will be installed at the PGV geothermal plant on the Big Island. In this first phase, it will not be connected to the grid. The electrolyzer will be operated in a dynamic mode designed to simulate future operation as a grid-connected variable load that can be quickly ramped up and down to provide frequency regulation. Data will be collected to analyze the ability of the electrolyzer to ramp up and down, and to determine its durability and performance under dynamic operating conditions. The hydrogen produced by the system will be used to fuel one bus operated by the County of Hawaii MTA. Schematics of the project concept are shown in Figures 1 and 2.

RESULTS

- Developed a model that shows the dynamic operation of the electrolyzer for managing grid frequency compared to a one-megawatt battery energy storage system that is installed on the Hawaii Electric Light Company grid (Figure 3).
- Completed site designs for the PGV and MTA dispensing sites.

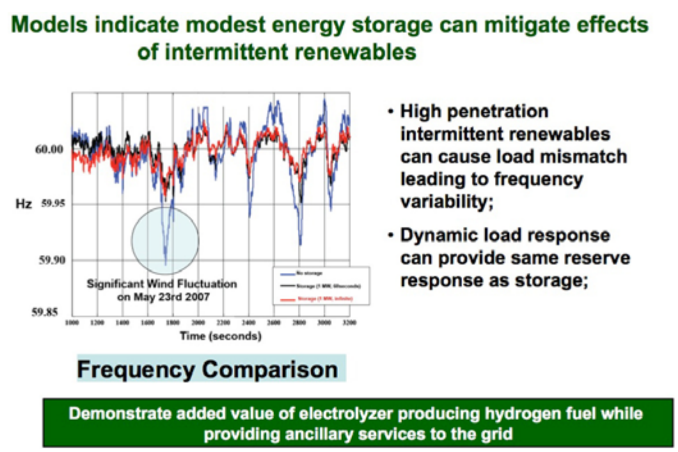

FIGURE 1. Effect of Dynamic Load Response on Grid Frequency

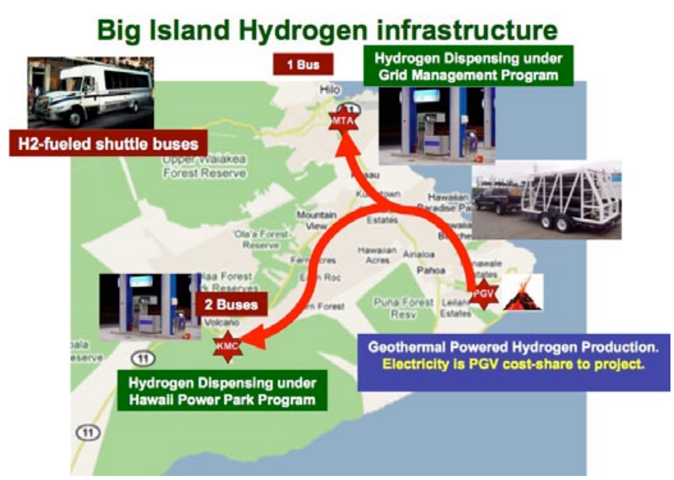

FIGURE 2. Hydrogen Production and Delivery System

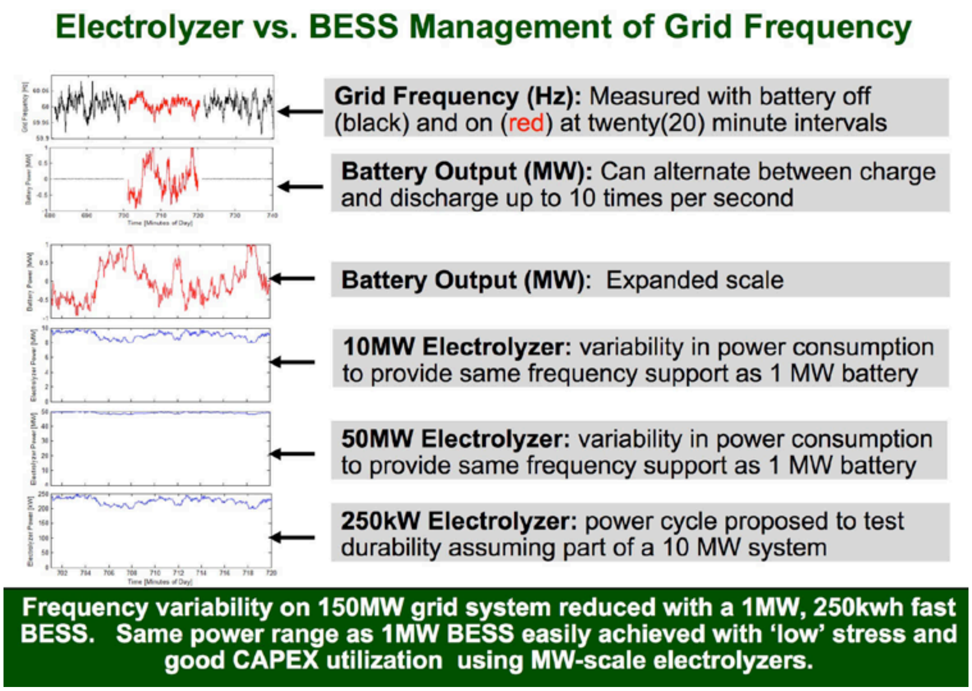

FIGURE 3. Comparison of a Battery Energy Storage System (BESS) with a Dynamically Operated Electrolyzer on Managing Grid Frequency

- Progressed legal agreements among project participants (PGV, MTA) including resolution of liability, indemnification, and insurance issues and requirements.
- Completed the construction of the hydrogen systems equipment and autonomous monitoring and control system and conducted a factory acceptance trial (Figure 4).
- Completed site designs for the PGV and MTA sites.
- Developed a scope of supply for the site improvements contractor.
- Completed a draft State of Hawaii Environmental Assessment, published a draft Finding of No Significant Impact, conducted a briefing to the local community where the project will be situated, and developed responses to community questions/comments.
- Completed First Responder training for over 300 first responders on the Island of Hawaii and Oahu utilizing the Pacific Northwest National Laboratory training program team and live fire "burn prop" that were deployed to Hawaii.

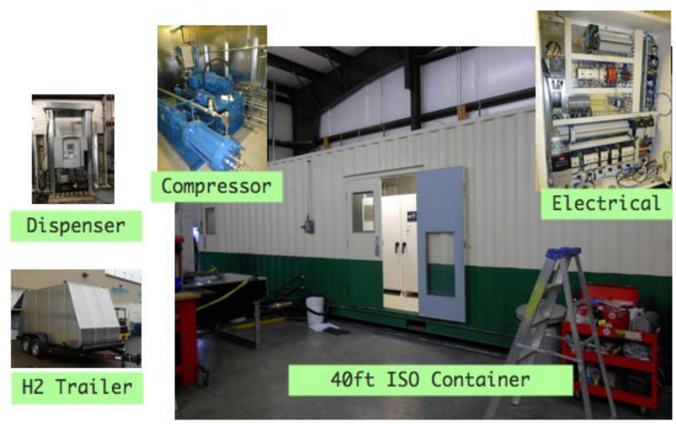

FIGURE 4. Hydrogen System Equipment

CONCLUSIONS AND FUTURE DIRECTIONS

- The project is underway but equipment and infrastructure need to be installed and operated before any results can be evaluated.
- Future work involves the procurement, installation, and operation of the following:
  - Installing hydrogen production systems and infrastructure at the PGV geothermal site
  - Installing hydrogen dispensing systems and infrastructure at the MTA bus depot site in Hilo
  - Procuring and operating a 19-passenger fuel cell electric bus
  - Operating the electrolyzer and hydrogen systems at the PGV and MTA sites

- Collecting and analyzing hydrogen system and fuel cell electric bus performance data
- Preparing performance reports and sharing it with project sponsors and industry

A major project challenge to the timely deployment of hydrogen infrastructure and equipment necessary to conduct operations has been the amount of time required to develop legal agreements to address liability issues. This is approaching two years in this project. This in turn has required our requesting no-cost extensions to extend the project to meet operational test duration requirements. This represents a large investment in outreach and education of all parties concerned including the legal profession, risk managers, first responders, and authorities having jurisdiction.

FY 2013 PUBLICATIONS/PRESENTATIONS

1. R. Rocheleau and M. Ewan, "*Hawaii Energy Systems as a Grid Management Tool*", *US DOE Annual Merit Review*, Washington, D.C., May 2012.

2. R. Rocheleau and M. Ewan, "*Hawaii Energy Systems as a Grid Management Tool*", *World Hydrogen Energy Conference*, Toronto, Canada. June 2012.