IX.3 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/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
- 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) 2014 Objectives

- 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 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 Environmental Assessment.
- Install site improvements and utilities at the PGV geothermal plant to support the operation of the hydrogen system.
- Install, commission, and operate the hydrogen system at PGV.
- Purchase a F-450 diesel truck to tow the tube trailer.
- Install a 350-bar hydrogen fuel dispenser at the County of Hawaii Mass Transit Agency (MTA) base yard in Hilo.
- Supply hydrogen for a fuel cell electric vehicle (FCEV) shuttle bus for local community bus service operated by the County of Hawaii MTA.
- Characterize performance/durability of the Proton proton exchange 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

(H) Footprint

(J) Renewable Electricity Generation Integration (for central)

(M) Control & Safety

Section 3.2.5 - Hydrogen Delivery Technical Barriers

(A) Lack of Hydrogen Carrier and Infrastructure Options Analysis

(B) Reliability and Costs of Gaseous Hydrogen Compression

(E) Gaseous Hydrogen Storage and Tube Trailer Delivery Costs

(I) Other Fueling Sites/Terminal Operations

(K) Safety, Codes, and Standards, Permitting

Section 3.3.5 - Hydrogen Storage Technical Barriers

(B) System Costs

(C) Efficiency

(F) Codes and Standards

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

(I) Dispensing Technology

Section 3.7.4 - Hydrogen Safety, Codes, and Standards

(D) Lack of Hydrogen Knowledge by AHJs (authorities having jurisdiction)

Section 3.8.5 – Education and Outreach

(D) Lack of Educated Trainers & Training Opportunities

Section 3.9.5 – Market Transformation Barriers

(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

(H) Utility and other Key Industry Stakeholders Lack Awareness of Potential Renewable Hydrogen Storage Application

(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

Technical Targets

No specific technical targets have been set.

FY 2014 Accomplishments

- Procured 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
- Contracted the Hawaii Center for Advanced Transportation Technologies to convert an ElDorado bus to an FCEV utilizing a Hydrogenics fuel cell power system
- Prepared draft responses to public comments
- Executed operations and maintenance contract to support daily operation of the hydrogen systems with Select Engineering Services
- Developed a draft Memorandum of Agreement with the County of Hawaii MTA
- Continued to work with PGV to progress Memorandum of Agreement; obtained PGV investor approval for the project

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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; and
- Long-term dynamic simulation.

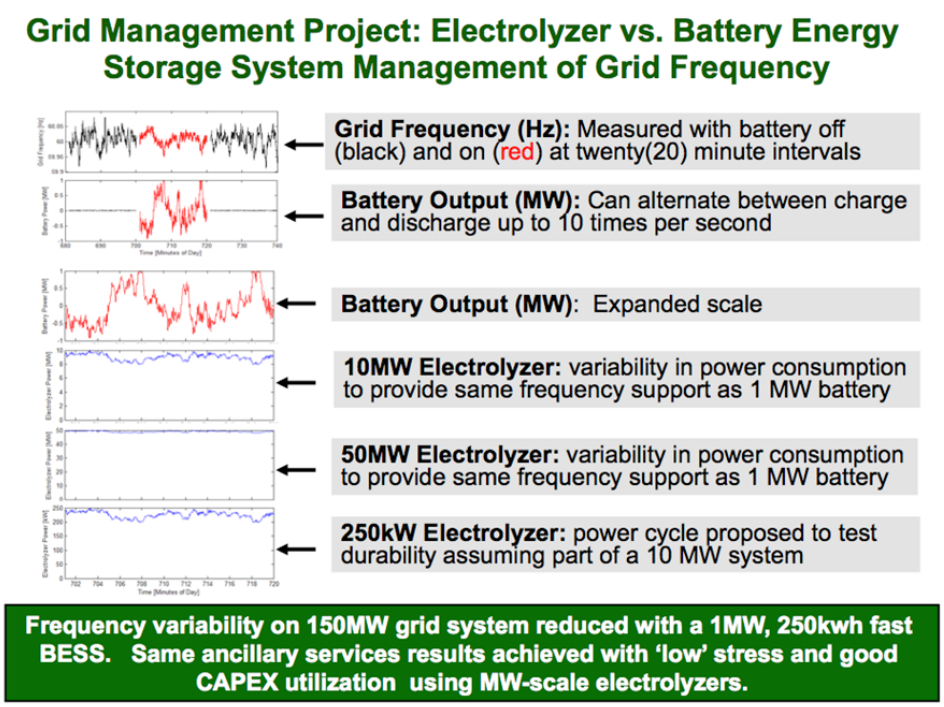
Frequency variability due to wind fluctuation of the Big Island grid was used as the initial test of the models. The Big Island grid has the following characteristics:

- 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 (Figure 1). The hydrogen produced by the system will be used to fuel one hydrogen-fueled bus operated by the County of Hawaii MTA. A schematic of the project concept is shown in Figure 2.

RESULTS

- Completed the manufacture of three Powertech 450-bar tube trailers used to transport hydrogen from PGV to the County of Hawaii MTA bus yard in the town of Hilo, and Hawaii Volcanoes National Park (Figure 3).
- Contracted the Hawaii Center for Advanced Transportation Technologies to convert an ElDorado bus to a FCEV utilizing a Hydrogenics fuel cell power system (Figure 4).
- Prepared draft responses to Draft Environmental Assessment Finding of No Significant Impact comments submitted by the public.
- Executed operations and maintenance contract to support daily operation of the hydrogen systems with Select Engineering Services.



BESS - battery energy storage sysem; CAPEX - capital expenditure

FIGURE 1. Comparison of a Battery Energy Storage System with a Dynamically Operated Electrolyzer Managing Grid Frequency

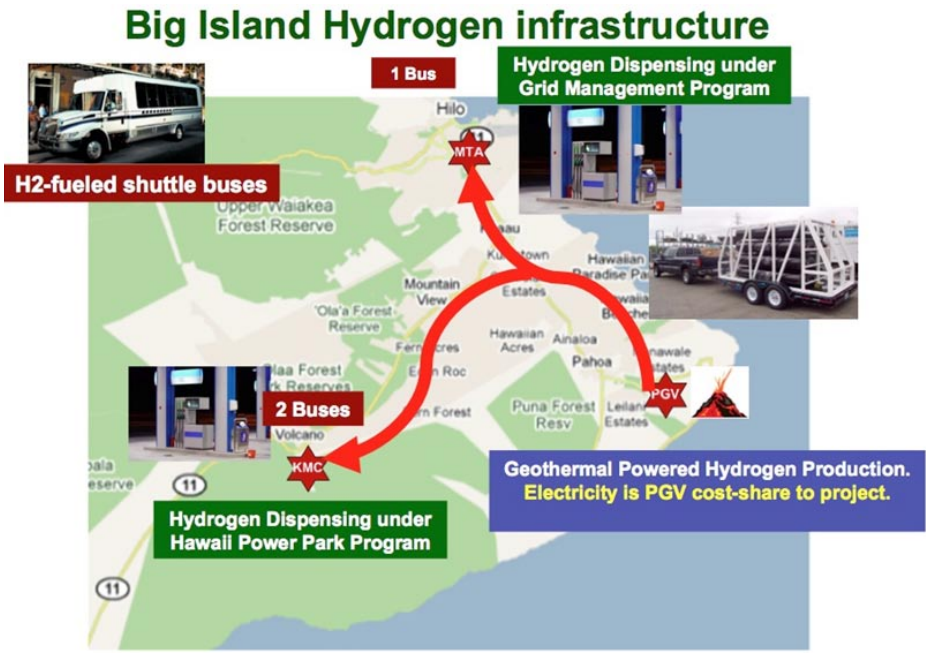


FIGURE 2. Hydrogen Production and Delivery System

FIGURE 3. Powertech Hydrogen Transport Trailers Ready for Delivery to Hawaii

FIGURE 4. First Hawaii Volcanoes National Park Bus Assembled in Honolulu by US Hybrid

- Developed a draft Memorandum of Agreement with the County of Hawaii MTA.
- Continued to work with PGV to progress Memorandum of Agreement; obtained PGV investor approval for the project.
- Completed design and fabrication of a fuel cell power system air filtration test stand (Figure 5). Used the test stand to quantify the adsorption capacity and breakthrough characteristics of commercial air filters that will be used in fuel cell electric buses at Hawaii Volcanoes National Park on the Island of Hawaii. This data will be used in collaboration with a "smart" onboard sensor system to prevent poisoning of the fuel cell power plant by the highly toxic environmental conditions. This test station has also been used over the past year to characterize and aid in the development of novel air purification materials, allowing HNEI to develop novel air filtration materials that are competitive with state of the art air filtration materials in both adsorption performance and cost.

CONCLUSIONS AND FUTURE DIRECTIONS

- Equipment and infrastructure need to be installed and operated before any results can be obtained and evaluated.
- Future work involves the procurement, installation, and operation of the following:

FIGURE 5. Fuel Cell Power System Air Filtration Test Station

- Installing hydrogen production systems and infrastructure at the PGV geothermal site
- Installing hydrogen dispensing systems and infrastructure at the County of Hawaii MTA bus depot site in Hilo
- Procuring and operating a 26-passenger fuel cell electric bus
- Operating the electrolyzer and hydrogen systems at the PGV and County of Hawaii MTA sites
- Transporting hydrogen in hydrogen transport trailers from the production site to dispensing sites at Hawaii Volcanoes National Park and County of Hawaii MTA
- Collecting and analyzing hydrogen system and FCEV bus performance data
- Preparing performance reports and sharing it with project sponsors and industry
- Conducting outreach activities with the public to inform them about hydrogen technologies.

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 four 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 2014 PUBLICATIONS/PRESENTATIONS

1. Ewan M., Oral presentation to an NREL sponsored workshop "Electrolytic Hydrogen Production Workshop", Golden, CO, February 28, 2014.

2. Ewan M., Oral presentation to US DOE & Industry Canada sponsored workshop "Hydrogen Energy Storage for Grid and Transportation Services", Sacramento, CA, May 14–15, 2014.

3. Ewan M., Rocheleau, R., Oral presentation at US DOE Annual Merit Review, "Hydrogen Energy Systems as a Grid Management Tool", Washington, DC, June 19, 2014.