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, 2012

Fiscal Year (FY) 2012 Objectives

- Conduct an environmental assessment for the installation of a hydrogen system at the Puna Geothermal Ventures (PGV) geothermal plant on the Island of Hawaii.
- Purchase a Proton 65 kg/day electrolyzer hydrogen production and compression system from Powertech. The system includes an autonomous data acquisition and control system to operate the hydrogen system.
- Install site improvements and utilities at the PGV geothermal plant to support the operation of the hydrogen system.
- Hire an operations and maintenance company to operate and maintain the hydrogen system.
- 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.
- Install and commission the hydrogen system at PGV.
- Procure two Powertech 450-bar tube trailers to transport hydrogen from PGV to the County of Hawaii Mass Transportation Agency (MTA) bus yard in the town of Hilo.
- Purchase a Ford 450 diesel pickup 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.
- 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.
- Supply hydrogen for a FCEV shuttle bus for local community bus service operated by the County of Hawaii MTA.
- Demonstrate the use of the Proton polymer electrolyte membrane (PEM) electrolyzers as a grid management tool to mitigate the impacts of intermittent renewable energy on the grid.
- Characterize performance/durability of the Proton PEM electrolyzer under dynamic load conditions.
- Conduct performance/cost analysis to identify benefits of integrated systems including grid services and off-grid revenue streams.

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 April 2009 edition (amended in 2011) of the Fuel Cell Technologies Program Multi-Year Research, Development and Demonstration Plan:

Hydrogen Production, Technical Challenges Section 3.1.4

(I) Grid Electricity Emissions (for distributed)
(J) Renewable Energy Generation Integration (for central)
(Q) Testing & Analysis

Technology Validation, Section 3.6.5

(A) Lack of Fuel Cell Vehicle Performance and Durability Data
(C) Hydrogen Storage
(D) Lack of Hydrogen Refueling Infrastructure Performance and Availability Data
(E) Codes and Standards
(G) Hydrogen from Renewable Resources

Hydrogen Safety, Section 3.8.4

(A) Limited Historical Database
(D) Liability Issues
(F) Safety is Not Always Treated as a Continuous Process

(G) Expense of Data Collection and Maintenance
(H) Lack of Hydrogen Knowledge by Authorities Having Jurisdiction
(I) Lack of Hydrogen Training Facilities for Emergency Responders

Technical Targets

No specific technical targets have been set.

FY 2012 Accomplishments

- Developed system requirements and specification
- Awarded contract to Powertech to supply "turn-key" hydrogen system
- Started environmental assessment
- Developed memorandum of agreement with PGV
- Developed memorandum of agreement with MTA
- Awarded contract to Powertech for additional hydrogen delivery trailers
- Developing site design with infrastructure contractor
- Procured additional $500k funding from State of Hawaii to purchase and convert the El Dorado bus to a FCEV bus
- Procured additional $1 million from the State of Hawaii H2 Fund for site infrastructure
- Procured additional $600k from Office of Naval Research for overall project support including purchase of additional hydrogen delivery trailers
- Engaged DOE Hydrogen Safety Team to support hydrogen safety
- Developed operations and maintenance contract to support daily operation of the hydrogen systems

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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. Curtailment and grid management-related costs 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 energy storage opportunity to mitigate curtailment and grid management costs by serving as a controllable load that produces a storable energy product during time periods where the electricity generation capacity is not required by the system operators. Energy storage via hydrogen production can provide the power producer or systems operator with increased options for coordinating system loads. 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 storage 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 energy systems:

1. Develop and validate rigorous analytic models for electricity and transportation.
2. Develop and model scenarios for the deployment of new energy systems including additional renewables.
3. 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.
4. Conduct testing and evaluation to validate potential solutions to facilitate utility acceptance.

General Electric (GE) was our subcontractor under a separate DOE funded project and we used the results of that for this project. However, GE is not a subcontractor under this specific project. GE developed two models of the Big Island grid utilizing GE's proprietary modeling technology. Transient performance was modeled using the GE Power Systems Load Flow software model:

- Full network model incorporating generator governors and automatic generator control
- Transient stability simulation looks at challenging times with fluctuating renewables to check transient stabilities
- Long-term dynamic simulation

A production cost model was developed using the GE Multi Area Production Simulation software model:

- 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 cost.

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

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

To explore the potential of the hydrogen energy storage 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 hydrogen-fueled bus to be operated by the County of Hawaii bus company - MTA.

Results

- Progressed legal agreements among project participants (PGV, MTA) including resolution of liability, indemnification, and insurance issues and requirements.
- Procured $1.5 million of additional funding from the State of Hawaii to augment DOE funding to support the installation of infrastructure and procurement of a 19-passenger FCEV shuttle bus.
- Awarded contract to Powertech for the supply of a "turn key" hydrogen system.
- Initiated an environmental assessment.

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 FCEV shuttle bus.
  - Operating the electrolyzer and hydrogen systems at the PGV and MTA sites.
  - Collecting and analyzing system performance data.
  - Preparing performance reports and sharing it with project sponsors and industry.
- If Phase 1 results show positive results, apply for a Phase 2 follow-on project that increases the size of the electrolyzer.

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 a no-cost extension 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. Hopefully follow-on projects will not take so long.

FY 2012 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.