X.3 Hydrogen Energy Systems as a Grid Management Tool

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Fiscal Year (FY) 2011 Objectives

- Demonstrate dynamic operation of electrolyzers as a grid management tool to mitigate the impacts of intermittent renewable energy on the grid.
- Characterize performance/durability of commercially available electrolyzers under dynamic load conditions.
- Provide hydrogen to fuel two Ford E-450 internal combustion engine shuttle buses for local community bus service operated by the County of Hawaii Mass Transit Agency.
- Conduct performance/cost analysis to identify benefits of integrated systems including grid services and off-grid revenue streams.

Technical Barriers

This project addresses the following technical barriers from the indicated sections of the April 2009 edition of the Fuel Cell Technologies Program Multi-Year Research, Development and Demonstration Plan:

Hydrogen Production, Section 3.1.4

(I) Grid Electricity Emissions

(J) Renewable Energy Generation Integration

(Q) Testing and Analysis

Technology Validation, Section 3.6.4

(H) Hydrogen from Renewable Resources

Hydrogen Safety, Section 3.8.4

(H) Lack of Hydrogen Knowledge by Authorities Having Jurisdiction

FY 2011 Accomplishments

- Developed overall system requirements and specification.
- Developed conceptual system design.
- Progressed legal agreements among project participants, including resolution of liability, indemnification, and insurance issues and requirements.
- Applied for additional funding from the State of Hawaii to augment DOE funding.
- Prepared and issued a request for proposal for the supply of the hydrogen system.
- Conducted a bidders' conference in Washington, D.C.
- Bids received and evaluated.
- Hydrogen system supplier selected.
- Initiated site design with infrastructure contractor.

Introduction

While solar and wind resources offer a major opportunity for supplying energy for electricity production and delivery systems, their variability and intermittency can raise significant interconnection challenges. At very high penetration levels, grid-operational issues caused by these renewable sources are a challenge and can lead to curtailment of the renewable resource, adding additional cost to the electricity supplied by these renewable resources. Hydrogen production through electrolysis may provide the means to mitigate curtailment and grid management costs by serving as a controllable load that varies in response to frequency signals from the grid. Such dynamic operation of the 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 revenue streams for 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

HNEI is using a four-step process to evaluate options to evolve the 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) including hydrogen production to address systems integration (grid stability) and institutional issues.
4. Conduct testing and evaluation to validate potential solutions to facilitate utility acceptance.

Under separate DOE and industry-funded efforts, HNEI has been conducting energy roadmapping and technology validation to identify economically viable technologies to transform island energy infrastructures. HNEI's subcontractor, General Electric (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 automated generation control.
- Transient stability simulation looking 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.
- Model outputs include 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 Puna Geothermal Ventures (PGV) geothermal plant on the Big Island. The electrolyzer will be operated in a dynamic mode designed to validate its ability to be 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 these dynamic operating conditions. The hydrogen produced by the system will be used to fuel two hydrogen-fueled buses to be operated by the County of Hawaii bus company.

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 County of Hawaii Mass Transit Agency bus depot site in Hilo.
  - Procuring and operating two Ford E-450 shuttle buses.
  - Operating the electrolyzer and hydrogen systems at the PGV and County of Hawaii Mass Transit Agency sites.
  - Collecting and analyzing system performance data.
  - Preparing performance reports and sharing it with project sponsors and industry.
- If results show positive results, apply for a phase 2 follow-on project that increases the size of the electrolyzers.

FY 2011 Publications/Presentations

1. R. Rocheleau and M. Ewan, "*Hydrogen Energy Systems as a Grid Management Tool,*" *US DOE Annual Merit Review*, Washington, DC. May 2011.

2. R. Rocheleau, "Hawaii Hydrogen Energy Storage Project," Electric Storage Association 21st Annual Meeting, San Jose, CA, June 6–9, 2011.