2014 Hydrogen and Fuel Cells Program Annual Merit Review Meeting

Hydrogen Energy Systems as a Grid Management Tool

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Project: MT008

Overview

Timeline

- ✓ **Project start date: 30 Sep 10**
- ✓ **Project end date: 29 Sep 14**
  No-cost extension requested
- ✓ **Percent complete: 70%**

Barriers

A. Inadequate standards and complex and expensive permitting procedures.

C. Inadequate private sector resources available for infrastructure development.

G. Lack of knowledge regarding use of hydrogen inhibits siting.

Budget

- ✓ **Expended as of 3/31/14: $3,740,000**
- ✓ **Total Project Value : $5,040,000**
- ✓ **Cost Share %: $3,000,000 (60%)**

Partners

- ✓ **US DOE:** Project Sponsor & Funding
- ✓ **NRL:** Federal Technical Program Manager
- ✓ **ONR:** Supplemental funding
- ✓ **HNEI:** Implementing Partner, Technical Lead
- ✓ **State of Hawaii**: Supplemental Funding
- ✓ **Puna Geothermal Ventures:**
  - ➢ Host site, Power, Water Provider**.**
- ✓ **County of Hawaii Mass Transit Agency:**
  - ➢ Host Site, Bus Operator
- ✓ **HCATT:** Bus Conversion.

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Relevance

Project Objectives

- ✓ **Demonstrate the use of electrolyzers to mitigate the impacts of intermittent renewable energy by regulating grid frequency;**
  - ➢ **Characterize performance/durability under dynamic load conditions;**
  - ➢ **Operate to simulate grid frequency regulation;**
- ✓ **Supply hydrogen to 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 & off-grid revenue streams;**
- ✓ **Support development of regulatory structure for permitting and installation of commercial hydrogen systems in Hawaii.**

This Reporting Period

- ✓ **Navigate the challenges of permitting, corporate and public acceptance, and codes & standards. (Barrier A).**
- ✓ **Continue to progress legal agreements to obtain access to cost effective renewable energy for hydrogen production; (Barrier C)**
- ✓ **Support risk management evaluations by corporate partners. (Barrier G)**

Approach: Utilize Low Cost Renewable Energy Resources

For hydrogen to be accepted in the marketplace it must be economically viable. For electrolytic hydrogen this requires low cost electricity + high capital utilization.

- ✓ **Utilize lowest cost, highest utilization factor renewable electricity to power electrolyzer;**
- ✓ **Central site production for highest capital utilization;**
- ✓ **Distributed dispensing sites with minimum complexity;**
- ✓ **Utilize additional revenue streams from monetization of ancillary services to subsidize hydrogen production cost;**
- ✓ **Leverage investment in other HI hydrogen projects (e.g. HCATT)**
- ✓ **Renewable electricity priority:**
  1. **Geothermal power: Lowest cost firm power;**
  2. **Hydropower: Competitive with geothermal;**
  3. **Wind: Potentially lowest $/kw-hr but intermittent;**
  4. **PV: Highest cost, highly intermittent.**

Approach: Central Site Production/Distributed Dispensers

H2-fueled shuttle buses

1 Bus

Hydrogen Dispensing under Grid Management Program

2 Buses

Geothermal Powered Hydrogen Production.
Electricity is PGV cost-share to project.

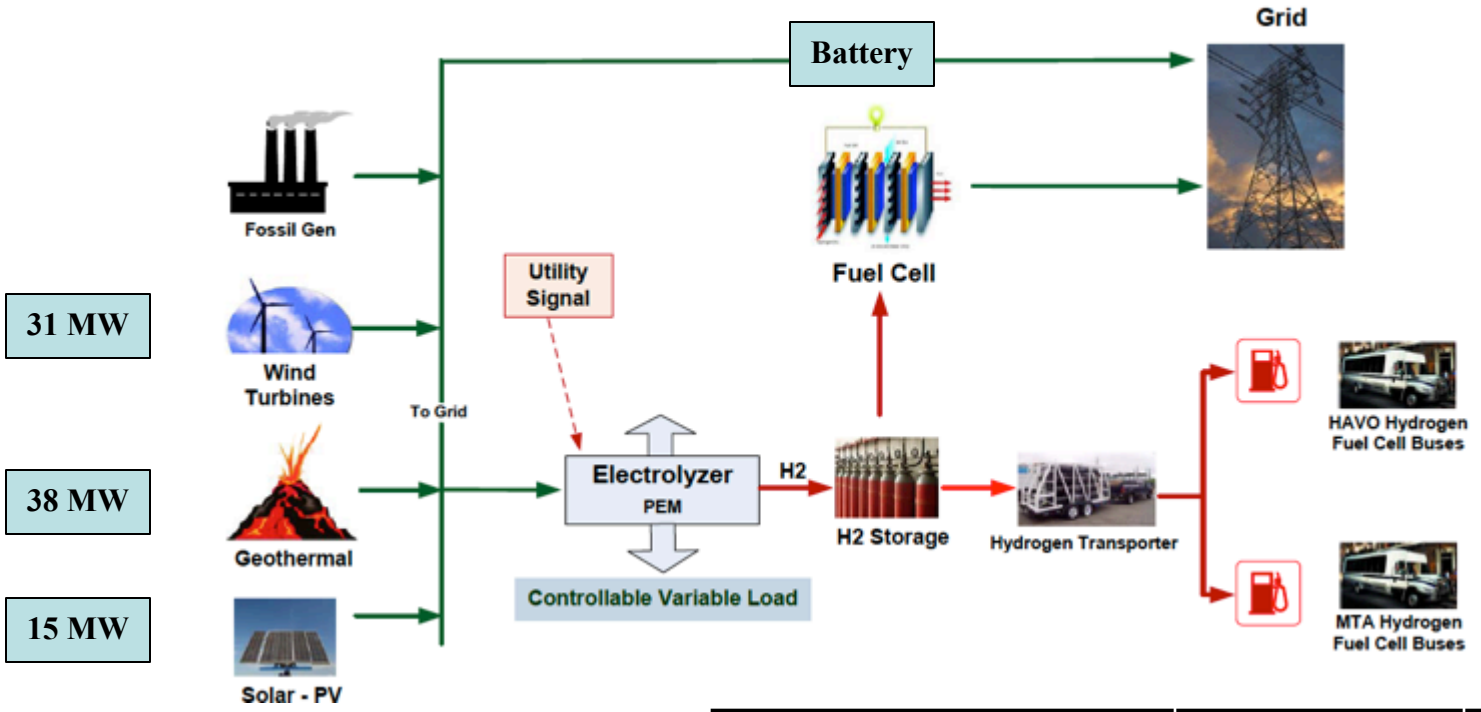
Hydrogen Dispensing under Hawaii Power Park Program

Approach: Utilize Lowest Cost Renewable Energy Resources

- ✓ **Go/No-go decision with Puna Geothermal Ventures (PGV) for the supply of geothermal electricity;**
  - **Environmental Assessment (EA) ready for approval;**
  - **Landowner barriers addressed;**
  - **Gain final approval from PGV project investors.**

- ✓ **Backup: Identify other potential providers of renewable electricity**
  - **Hydro (Kau coffee mill)**
  - **Wind (South point wind farm)**
  - **Solar (NELHA)**

Approach: Assess & Compare Electrolyzers to BESS



Critical Assumption

Electrolyzers will be able to be operated dynamically without major degradation and loss in performance

Service	Electrolyzer	Battery
Up Reserve	Yes	Yes
Down Reserve	Yes	Yes
Up Regulation	Yes	Yes
Down Regulation	Yes	Yes
Fuel Production	Yes	**No**
Voltage/VAR Support	**No**	Yes

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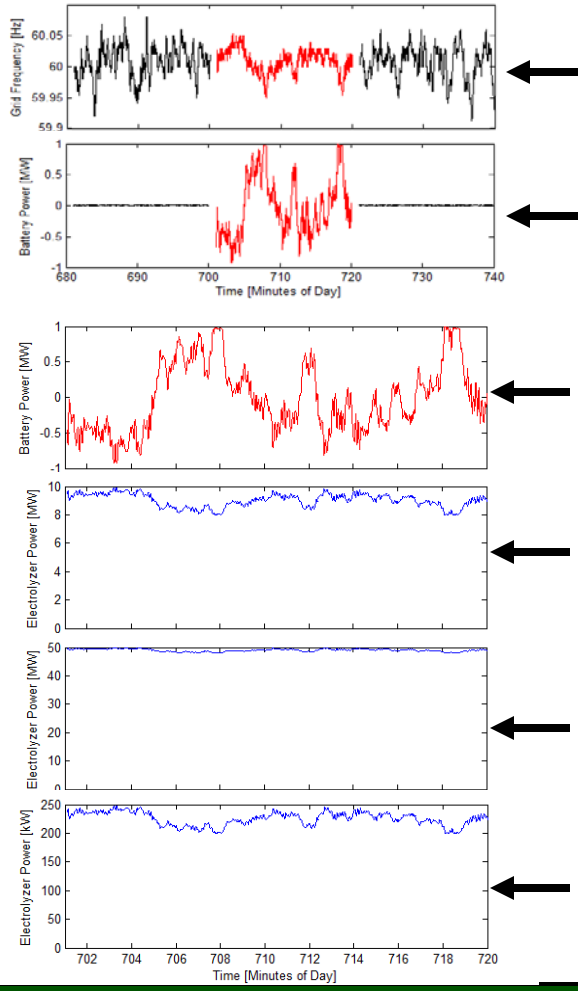
Accomplishment: Conducted Analysis to Justify Electrolyzer Approach



Grid Frequency (Hz): Measured with battery off (black) and on (red) at twenty(20) minute intervals

Battery Output (MW): Can alternate between charge and discharge up to 10 times per second

Battery Output (MW): Expanded scale

10MW Electrolyzer: variability in power consumption to provide same frequency support as 1 MW battery

50MW Electrolyzer: variability in power consumption to provide same frequency support as 1 MW battery

250kW Electrolyzer: power cycle proposed to test durability assuming part of a 10 MW system

Frequency variability on 150MW grid system reduced with a 1MW, 250kwh fast BESS. Same power range as 1MW BESS easily achieved with 'low' stress and good CAPEX utilization using MW-scale electrolyzers.

Accomplishments

- ✓ Continued to refine the Environmental Assessment - brought to point of final approval;
- ✓ Completed the manufacture three hydrogen transport trailers;
- ✓ Initiated discussions with major petroleum distributor to provide operators to haul trailers. Addresses certifications & safety requirements;
- ✓ Issued contract for the purchase and conversion of 19 passenger FCEV shuttle bus by US Hybrid for use by the County of Hawaii Mass Transit Agency.
  - ➢ 19 passenger, 150 mile range on 10 kg H2 + Johnson Controls Li battery,
  - ➢ 30 kW Hydrogenics fuel cell power system.

Accomplishments

- ✓ **Progressed negotiations with PGV investors;**
  - ➢ **Introduced concept of utilizing electrolyzers to control grid frequency to major utility PGV investor.**
- ✓ **Investigated other renewable electricity options:**
  - ➢ **Curtailed wind at South Point – not viable due to infrastructure requirements;**
  - ➢ **Hydro power Installation – 3/14 – viable**;
    - **New 400 kW hydro being installed. ~300kW available 24/7 for hydrogen production;**
    - **Needs permits & equipment installation.**
  - ➢ **PV farm at NELHA– viable.**
    - **1 MW array to be installed;**
    - **~9 hours per day of power available for electrolyzer. Max 24kg H2 production per day = 4.5 days to fill trailer;**
    - **Not as attractive as hydro or geothermal due to low capacity factor;**
    - **Use as fallback option.**

Accomplishments

Completed design and manufacture of first automated FCEV bus air filtration system Environmental Sensor Array (ESA):

- **HAVO buses will demonstrate ability to operate in challenging high contaminant environment (up to 5ppm SO_2);**
- **Leveraged ONR funds to develop custom filtration systems**
  - **Use commercially available SO_2 filters while developing novel regenerative purification materials;**
  - **Collect real-time *environmental conditions*, *filter performance* and *fuel cell performance* data while fuel cell buses are under operation & display to operator.**
- **Prototype ESA system delivered to US Hybrid for testing and integration engineering into first FCEV bus – 4/14.**

Analysis of the data will provide USDOE/DOD/Navy with understanding of durability & performance of FCEVs in challenging environments utilizing state-of-the-art air filtration technology.

Responses to Previous Year Reviewer's Comments

- ✓ **FY13 Reviewer Comment: It has taken too long to get all permissions and to put the equipment in place.**
  - ➢ **FY14 Response:**
    - **Agree but this is a real-world market transformation. The delay is outside the ability of the project to influence due to third party investors and existing legal agreements that need to be modified;**
    - **The utilities and investors in the PGV geothermal plant have been cautious about introducing hydrogen systems requiring substantial effort to educate them on risks and benefits;**
    - **Investors and Ormat have invested significant time, financial, technical, and legal resources to evaluate the technical, financial, and business risks;**
    - **The good news: Project has been informed that Ormat, PGV, and its investors are fully committed to the project moving forward;**
    - **This effort, while time-consuming and frustrating for all, is helping to overcome Barrier G: Lack of Knowledge regarding use of hydrogen inhibits siting.**

Responses to Previous Year Reviewer's Comments

- ✓ **FY13 Reviewer Comment: It seems that all the work is through modeling and not through the actual installation and connection to the grid.**
  - ➢ **FY14 Response:**
  - ▪ **A limited amount of modeling has been conducted to assess the ability of the electrolyzer to provide grid services and to design experiments;**
  - ▪ **Primary effort to date has been focused on procuring and installing the equipment, and getting legal agreements in place;**
  - ▪ **Experiments planned to validate the dynamic performance and degradation of the electrolyzer over an extended duration.**
  - ✓ **FY13 Reviewer Comment: The project team should add an explicit task to develop an analytical format for comparing the benefits of the hydrogen approach with the battery approach.**
  - ➢ **FY14 Response:**
  - ▪ **Due to differences in capacity this will be accomplished via analysis of cycling experiments and grid models which have been developed for assessment of BESS performance.**

Collaborations

- ✓ **US Department of Energy:** Project Sponsor & Funding;
- ✓ **Naval Research Laboratory:** Federal Technical Program Manager;
- ✓ **Hawaii Natural Energy Institute:** Implementing Partner, Technical Lead;
- ✓ **Office of Naval Research:** Supplemental Funding;
- ✓ **State of Hawaii:** Cost Share;
- ✓ **Puna Geothermal Venture:** Host Site, Provide Power and Water (Cost Shared);
- ✓ **County of Hawaii Mass Transit Agency:** Host Site, Bus Operator (Cost Shared);
- ✓ **Hawaii Volcanoes National Park:** Host Site, Bus Operator;
- ✓ **HCATT:** Conversion of Shuttle Bus;
- ✓ **HELCO:** Interested Observer, Potential Partner for Grid Analysis;
- ✓ **Hydrogen Safety Panel:** Design Safety Review;
- ✓ **PNNL:** First Responder Training;
- ✓ **Geometrician:** Environmental Assessment Support Services.

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Target Dates for Future Work

- ✓ "Go/No-Go" Decision with PGV 6/14
- ✓ PGV "Go" Option
  - ➢ Install infrastructure at PGV 12/14
- ✓ Alternative to PGV Option
  - ➢ Hydro Power Option – "Go/No Go" 7/14
  - ➢ PV option – "Go" 7/14
  - ➢ Install Infrastructure at Hydro or PV sites 12/14
- ✓ Install infrastructure at MTA & HAVO sites 12/14
- ✓ Complete MTA shuttle bus conversion 5/15;
- ✓ Operate systems 1/15 – 12/15;
- ✓ Collect & analyze data 1/15 – 12/15;
- ✓ Prepare performance reports 1/15 – 12/15;

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Summary

Objective: Demonstrate the durability of electrolyzers operated in cyclic mode appropriate to mitigate the impacts of intermittent renewable energy.

Relevance: Electrolysis of water to produce hydrogen could contribute significantly to Hawaii fuel needs while providing needed support for grid connected intermittent renewables;

Added value of using electrolyzer to provide grid ancillary services will expand market opportunities.

Will help validate costs required to justify large scale electrolysis for fuel production.

Approach: Install automated autonomous electrolyzer production system at site of renewable energy production. Validate durability and performance under sustained cyclic operation. Deliver hydrogen to FCEV bus operators. Demonstrate performance to operators and public;

Accomplishments: Procured three hydrogen transport trailers, progressed agreements for siting system at geothermal plant, identified fallback production sites, initiated procurement of FCEV shuttle bus, completed design and manufacture of first FCEV bus air filtration system, initiated data acquisition and analysis plans

Collaborations: Strong team comprised of cooperating federal departments (DoD, US DOE, NPS), State, County, and private industry.

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