2013 Hydrogen and Fuel Cells Program Annual Merit Review Meeting

Hydrogen Energy Systems as a Grid Management Tool

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Project: MT008

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Overview

Timeline

- ✓ **Project start date: 30 Sep 10**
- ✓ **Project end date: 29 Sep 13**
  No-cost extension requested
- ✓ **Percent complete: 60%**

Barriers

- ✓ **Hydrogen Production**
  - ➢ **J: Renewable electricity generation integration**
- ✓ **Technology Validation**
  - ➢ **E: Codes & Standards**
- ✓ **Non-technical issues preventing full commercialization of hydrogen**

Budget

- ✓ **Total project funding:**
  - ➢ **US DOE: $1,796,515**
  - ➢ **State of Hawaii: $1,500,000**
  - ➢ **ONR: $600,000 ONR**
  - ➢ **US DOE: $500,000**
- ✓ **Funding Received in FY12: $500,000**
- ✓ **Funding for FY13: $0**

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
- ✓ **HELCO: Potential partner for expanded program**

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Objective:
Evaluate Hydrogen Energy Systems for Grid Management

- ✓ **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 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; and**
- ✓ **Evaluate effect on reducing overall hydrogen costs offset by value-added revenue streams.**

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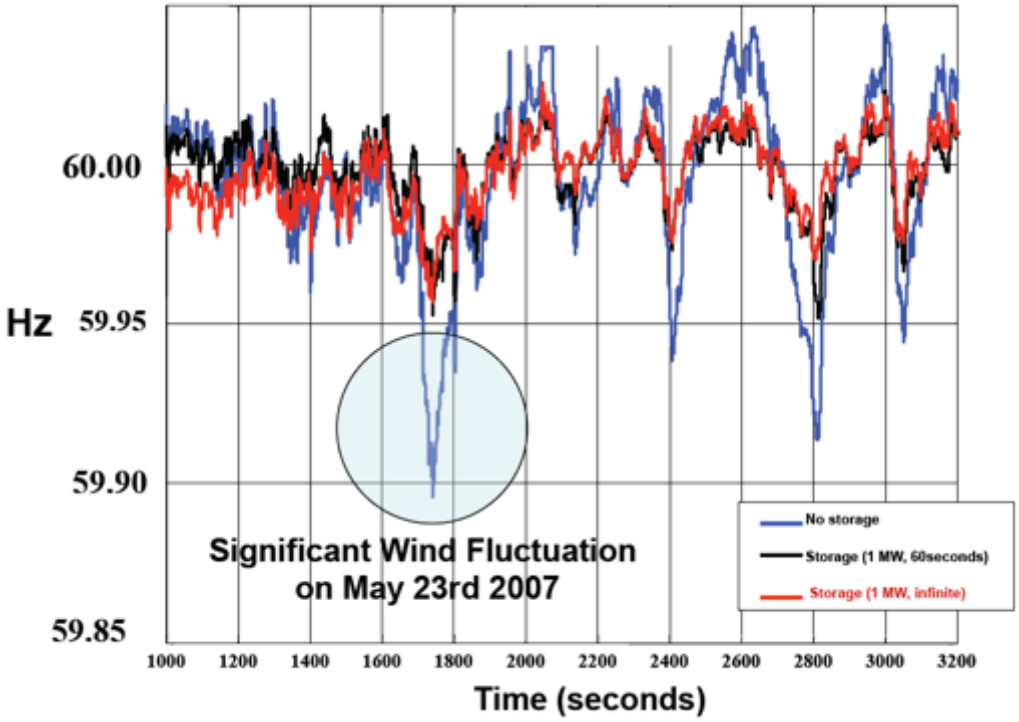
Relevance:

Models indicate modest energy storage can mitigate effects of intermittent renewables



Frequency Comparison

- **High penetration intermittent renewables can cause load mismatch leading to frequency variability;**
- **Dynamic load response can provide same reserve response as storage;**

Demonstrate added value of electrolyzer producing hydrogen fuel while providing ancillary services to the grid

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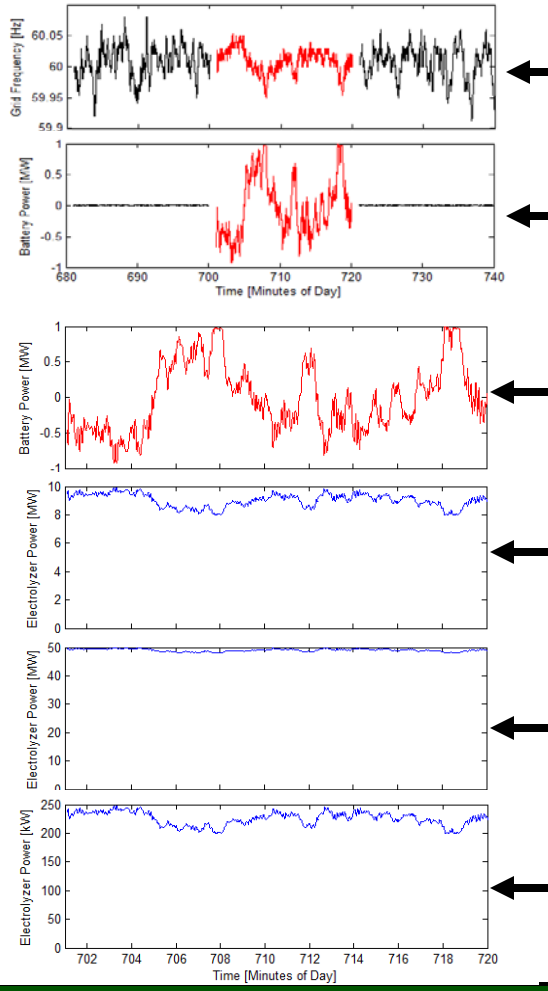
Relevance:

Electrolyzer vs. BESS Management of Grid Frequency



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

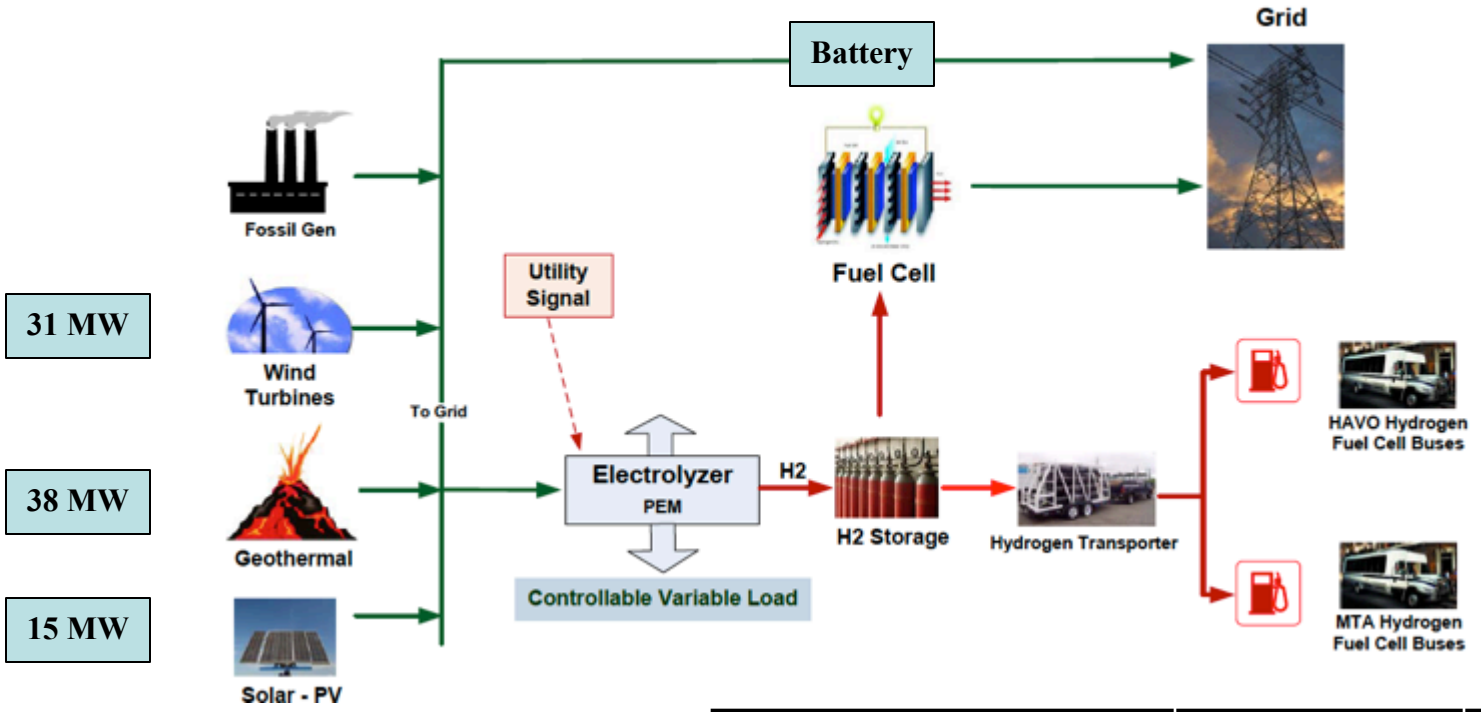
50MW Electrolyzer: variability in power consumption to provide same frequency support as 1 MW battery

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.

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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Approach:

Big Island Hydrogen infrastructure

H2-fueled shuttle buses

1 Bus

Hydrogen Dispensing under Grid Management Program

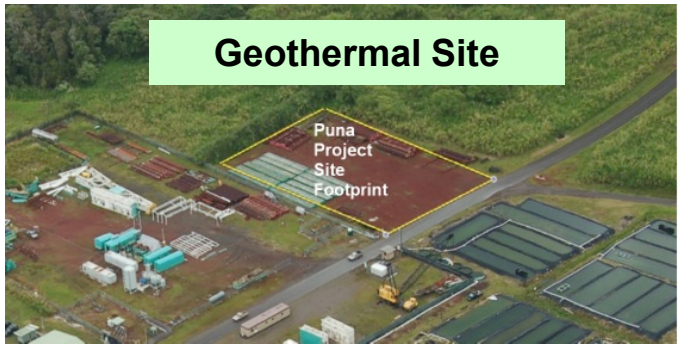
2 Buses

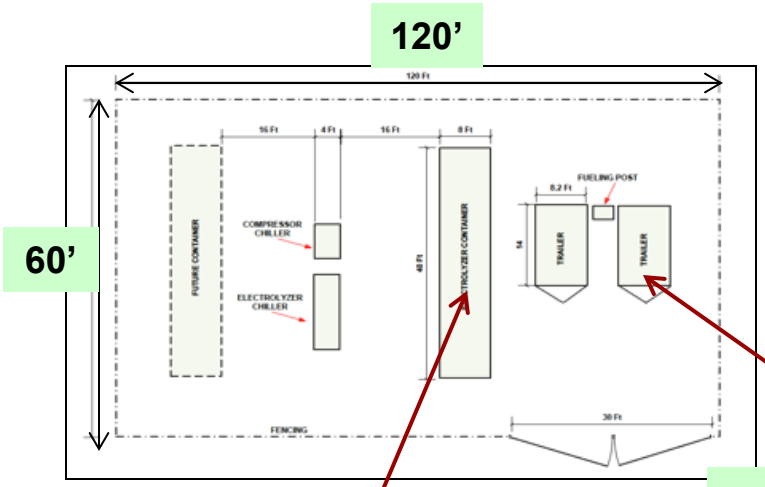
Hydrogen Dispensing under Hawaii Power Park Program

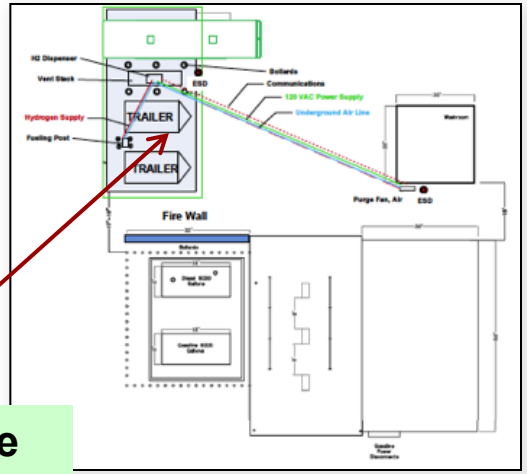
Geothermal Powered Hydrogen Production.
Electricity is PGV cost-share to project.

Accomplishments:

Completed Site Designs







40’ ISO Container
- **Electrolyzer**
- **Compressor**
- **Control System**
- **Electrical Distribution**

105 kg H2 Tube Trailers

Cascade fill process eliminates compressor, related infrastructure, and O&M costs at dispensing site.

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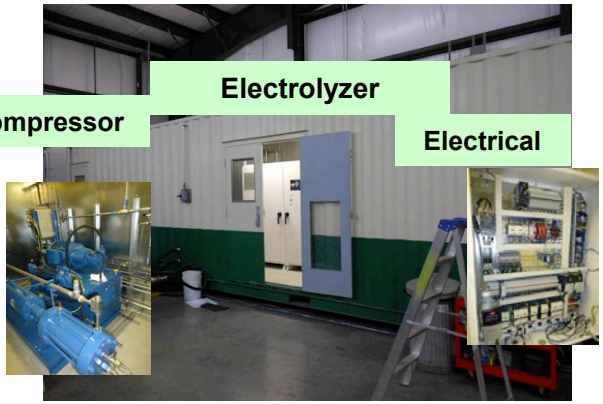
Accomplishments:
Equipment Factory Acceptance Trial 12/12

- ✓ **Autonomous Data Acquisition, Monitoring & Control System**
  - All systems capable of being remotely monitored and operated through a system of sensors, remotely operated valves, & circuit breakers;
  - Safety systems are independent and hardwired to active elements;
- ✓ **Hydrogen Production & Compression Module**
  - Integrated into 40' ISO container
  - Proton 65 kg/day electrolyzer system
  - HydroPac Compressor
  - Control system



- ✓ **Hydrogen Dispensing System**
  - Hydrogen tube trailer – 105 kg H2 @ 450 bar
  - Hydrogen fueling post interfaces between tube trailer & dispenser;
  - Hydrogen dispenser

H2 Trailer

Fueling Post

Dispenser

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Accomplishments:

First Responder Training Feb 2013

- Utilized PNNL training program;
- Trained 300 first responders from Oahu and Big Island;
- Classroom & field work covering hydrogen and electrical;
- Live fire with “Burn Prop”;

- Enthusiastic reception by fire departments and civil defense;
- Effective public outreach & promoted community acceptance;

- Sets groundwork for operational phase.

Accomplishments:

Progressed Environmental Assessment

- ✓ **Completed draft Environmental Assessment (EA) – 10/12;**
  - **First H2 project EA in State of Hawaii, other H2 fueling projects on Federal land;**
  - **Made initial "Finding Of No Significant Impact": (FONSI);**
  - **Published on internet for public comment;**
- ✓ **EA presented to local community – 10/12;**
- ✓ **Received over 40 comments;**
  - **Some residents oppose project due to concerns about potential for increased geothermal production;**
- ✓ **Developed responses to public comments: 04/13**
- ✓ **Preparing to disseminate responses and make final decision.**

Key Dates

- ✓ **Q4/10**– Start Contract, complete conceptual design, system specifications;
- ✓ **Q1/11**–Issued RFP for "Turn-Key" H2 equipment. Draft MOA from Ormat (PGV);
- ✓ **Q2, 3/11**– Powertech selected for H2 equipment, Ormat MOA reviewed by UH Legal, No bus decision by Ford, secured $1 million from State H2 Fund for site infrastructure.
- ✓ **Q4/11**– Ormat MOA reviewed by Ormat Legal, agreement with AFRL HFCB program for NRE estimated at $750k, secured $500k from State for purchase/conversion of HFCB;
- ✓ **Q1/12** –Powertech PO executed, continued work on Ormat MOA, developed SOW for EA consultant, obtained draft letter of support from County of Hawaii Planning Department (controls geothermal resource), secured Ormat electrical supply tie-in;
- ✓ **Q2/12** – Issued EA PO, Ormat Legal completed 2nd review, requested no-cost 1-year contract extension from NRL, hydrogen equipment fab started at Powertech;
- ✓ **Q3/12** – Draft EA FONSI to State Office of Environmental Quality Control for publication & public comment period, received no-cost extension to 30 Sep 2013, conducted site visits and design reviews including participation of Hydrogen Safety Panel, site designs for PGV and MTA completed, H2 systems 80% complete;
- ✓ **Q4/12** – EA presentation to local community, Ormat identified need for Consent Decree from land owner, H2 equipment completed, Field-acceptance trials held Dec 2012.
- ✓ **Q1/13** – First Responder training by PNNL in Feb, Ormat negotiation with landowner.

Major Schedule Drivers: PGV MOA (~2.5 years), EA (~1 year).

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

- ✓ *Install infrastructure at PGV and MTA sites 7/13;
- ✓ Install & commission hydrogen systems at PGV & MTA sites 8/13;
- ✓ Procure and convert shuttle bus 12/13;
- ✓ Operate systems 1/14 – 12/14;
- ✓ Collect & analyze data 1/14 – 12/14;
- ✓ Prepare performance reports 1/14 – 12/14;
- ✓ Install alkaline electrolyzer for side-by-side comparison with PEM electrolyzer (tbd contingent on demand for H2)

*contingent of resolution of easement rights between ORMAT and landowner

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FCEB Air Contaminant Study

- ✓ **Three (3) El Dorado shuttle buses being converted by HCATT**
  - ➢ **19 passengers, 150 mile range on 10 kg of H2 + Johnson Controls Li battery**
  - ➢ **Hydrogenics 30 kW fuel cell power system**
- ✓ **Leverages AFRL NRE on first bus conversion for USAF;**
- ✓ **FCEBs H2 requirements supported by geothermal project;**
- ✓ **HAVO buses will demonstrate the ability to operate in challenging high contaminant environment (up to 5ppm SO_2).**
- ✓ **Leverages 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**

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

Summary

Objective: Demonstrate the use of electrolyzers to mitigate the impacts of intermittent renewable energy by regulating grid frequency while offsetting the cost of hydrogen through value added services.

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

Validate grid behavior models utilizing significant electrolysis.

Costs required to justify large scale electrolysis for fuel need to be determined.

Approach: Install automated autonomous electrolyzer production system at geothermal plant. Validate durability and performance under sustained cyclic operation. Deliver hydrogen to FCEB operators. Demonstrate performance to operators and public;

Accomplishments: Hydrogen system equipment and data acquisition control system built and tested. Site designs completed. Contracts prepared to install systems. Environmental Assessment prepared. First Responder training completed.

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

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