Hydrogen Energy Systems as a Grid Management Tool

PI: Dr. Richard Rocheleau

Presenter: Mitch Ewan

Hawaii Natural Energy Institute

School of Ocean and Earth Science and Technology

University of Hawaii

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Project: MT008

HNEI Hawai'i Natural Energy Institute University of Hawai'i at Mānoa

Overview

Timeline

- ✓ **Project start date: 30 Sep 10**
- ✓ **Project end date: 29 Sep 15**
- ✓ **Project continued using non USDOE funds**

Barriers

A. Inadequate standards and complex and expensive permitting procedures.

C. Inadequate private sector resources available for infrastructure development.

H. Utilities lack awareness of potential renewable hydrogen storage applications.

Budget

- ✓ **Total Project Value : $5.767M**
  - ✓ **US DOE: $2.0M**
  - ✓ **SOH: $1.126M**
  - ✓ **Navy: $2.641M**
- ✓ **Expended as of 4/10/18: $5.44M**
- ✓ **Cost Share (%): $3.77M (188%)**

Partners

Cost Share Partners

- ✓ **US DOE:** Project Sponsor & Funding
- ✓ **ONR:** Cost Share
- ✓ **State of Hawaii**: Cost Share
- ✓ **NELHA:** Host site and Cost Share.
- ✓ **County of Hawaii:** Bus Operator & Cost Share
- ✓ **HCATT:** Bus Conversion and Cost Share
- ✓ **US Hybrid:** Bus Conversion & Cost Share

Related Supporting Projects

- ✓ **NRL:** Federal Technical Program Manager

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Relevance
Grid Frequency Management

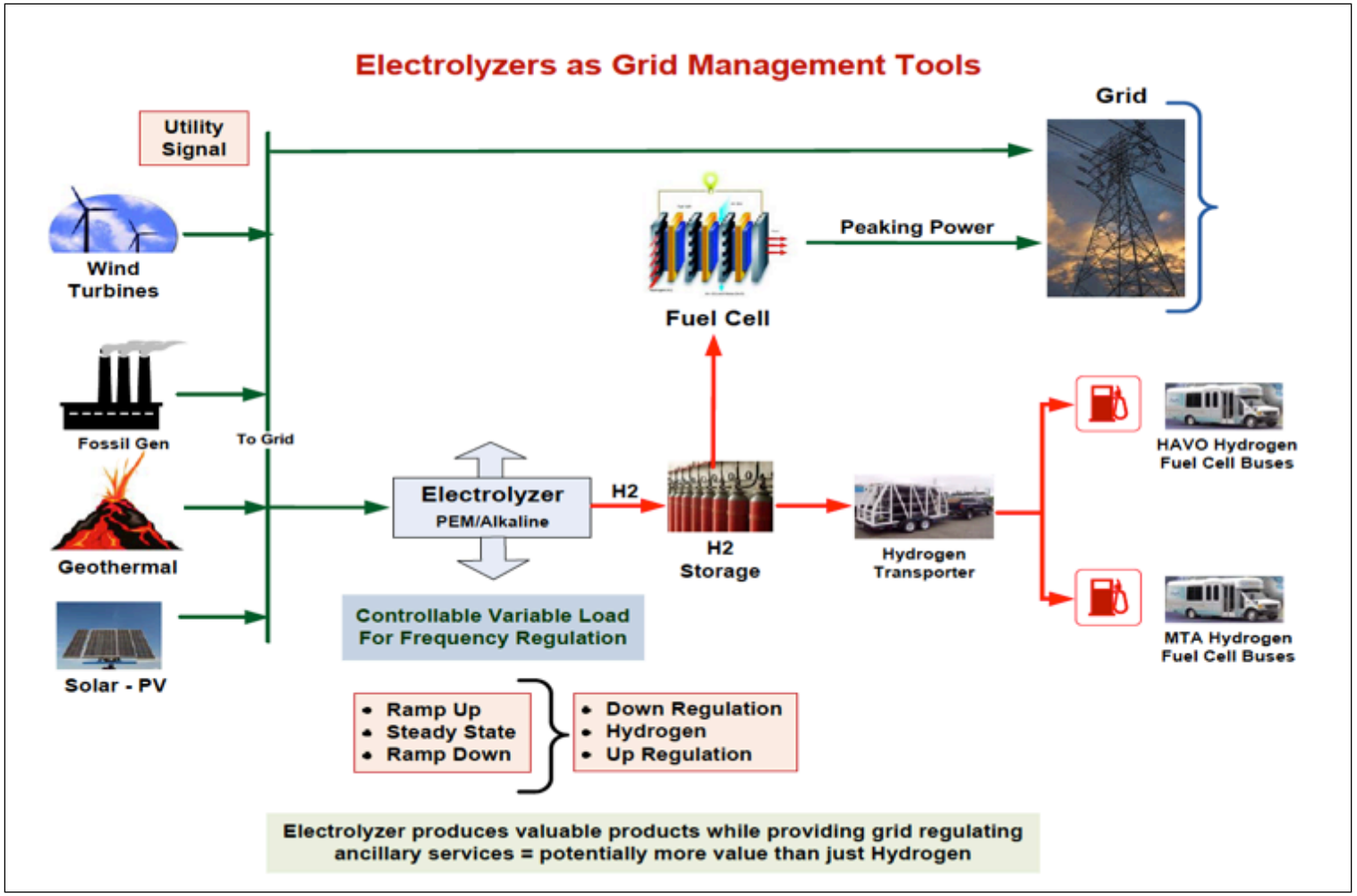
- ✓ **Electric power grids operate at a frequency of 60 Hz;**
- ✓ **Deviation from 60 Hz is a measure of the load balance of the grid – load matched to generation;**
- ✓ **With increased penetration of intermittent renewables on the grid the supply and grid frequency may be subject to fluctuations;**
- ✓ **Grid operators can stabilize the frequency by ramping power generation up/down or controlling variable loads or storage;**
- ✓ **Project Thesis: An electrolyzer can be used as a variable controllable load that can be reduced/increased in order to maintain the total load balance and frequency stability.**

Relevance

Project Objectives

- ✓ **Validate the performance, durability & cost benefits of grid integrated hydrogen systems (C, H);**
  - ➢ **Demonstrate dynamic operation of electrolyzers to mitigate impacts of intermittent renewable energy (H);**
  - ➢ **Demonstrate potential of multiple revenue streams from monetization of ancillary services and producing hydrogen (H);**
  - ➢ **Supply hydrogen to shuttle buses operated by County of Hawaii Mass Transit Agency (MTA), and Hawaii Volcanoes National Park (HAVO) (C);**
- ✓ **Support development of regulatory structure for permitting and installation of hydrogen systems in Hawaii (A).**

Approach



HNEI's concept to use an electrolyzer to provide grid ancillary services such as up-regulation, down-regulation, and off-peak load.

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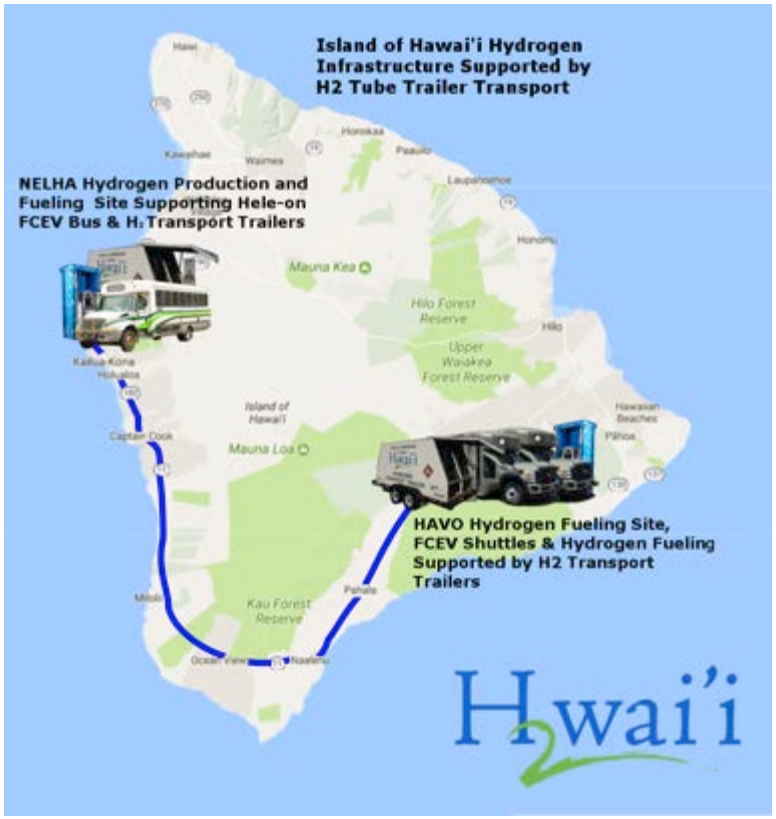
Approach

Central Site Production/Distributed Dispensing (A, C, H)

Economically viable electrolytic hydrogen will require low cost electricity + high capital utilization.



- ✓ **Central site production for highest capital utilization;**
- ✓ **Distributed dispensing sites with minimum complexity to reduce fuel distribution costs;**
- ✓ **Optimize additional revenue streams from:**
  - ➢ **Quantify and monetize ancillary services;**
  - ➢ **Sale of hydrogen for transportation.**

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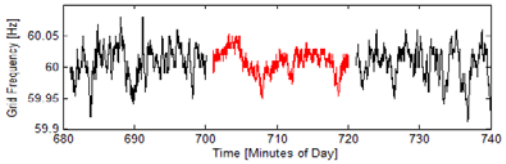
Approach

Use of Electrolyzer for Grid Ancillary Services (H)



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

- **HNEI demonstrated ability to regulate grid frequency on 150MW grid with a fast-acting 1MW battery;**
- **Cycling tests suggest electrolyzer more appropriate for slower-acting changes;**
- **Battery/electrolyzer hybrid may provide grid services across broad range of operating conditions;**
- **Using electrolyzer as a variable load as opposed to battery allows effective use of CAPEX plus other value added services.**

Approach

Locate Central Site Production at NELHA (A,C,H)

- **State of Hawaii facility:**
  - **Strong political & financial support;**
  - **Significant cost share provider;**
  - **Leverages available technical staff.**
- **Ease of permitting;**
- **Existing infrastructure reduces site costs;**
- **Kona Airport offers opportunity to leverage project:**
  - **Airport ground handling equipment;**
  - **Airport shuttle buses;**
  - **Rental cars.**
- **Supports NELHA Vision of a "Hydrogen Hub";**
  - **Provides "enabling" infrastructure to attract new projects.**

Accomplishments – Site Completed

- ✓ Completed NELHA site infrastructure installation;
- ✓ NELHA site building permits approved by AHJ:
  - Educated AHJ. Follow-on permits will be much easier;
  - First non-federal site.
- ✓ Reduced hydrogen transport cost by ~50%:
  - Modified hydrogen transport trailers to improve cascade fill utilization from 50% to 90% .
  - Completed design, fabrication, testing of new boost compressor fueling post.
- ✓ Recertified hydrogen transport trailer composite cylinders.

Accomplishments

Installed NELHA Hydrogen System (A,C)

Site Layout

Site Preparation

Excavation

Concrete Pad

Equipment Installation

Setting Equipment
20-ton Lift

Site Work Completed

Tube Trailer Filling Bays

Dispenser

Accomplishments

Converted 3 Buses

County of Hawaii Bus (1) 29 Pass

HAVO Bus (2) 19 Pass

- **Hawaii MTA Fuel Cell Electric Hybrid Shuttle Buses demonstrate to the general public the advantages of fuel cell buses and electric drive.**
  - **Quiet ride;**
  - **No diesel fumes;**
  - **Potential for lower O&M costs (need low cost hydrogen).**
- **HAVO Buses will demonstrate HNEI's "Smart" air filtration sensor systems in a high air contaminant environment.*** **(Funded by ONR).**

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Accomplishments

Recertified 3 Hydrogen Transport Trailers

- Hydrogen Transport Trailer carries 105 kg @ 450 bar;
- Demonstrate distributed dispensing using cascade fill to 350 bar using a "Smart" dispenser;
- Trailer O&M costs will be evaluated including US DOT hydrostatic testing requirement every 5 years;
  - Currently no facility in Hawaii can hydro test cylinders of this size:
  - Must be shipped to mainland (very costly and time consuming);
  - Recertified Trailers before shipping to Hawaii to give us a full 5-year window.

Responses to Previous Year Reviewer's Comments

- ✓ **FY17 Reviewer Comment: Lack of true field data after seven years under development is a weakness.**
  - **FY18 Response: Cannot obtain data without a working system to generate the data. Recognizing the delays in developing the site were going to be a major problem, we proactively operated the system for 7 months at the manufacturer to obtain baseline data prior to shipping the equipment and tasked a research team to analyze the data. The analysis identified significant areas related to electrolyzer response rates in dynamic operation, and electrolyzer control system functionality. Yes there have been major delays in installing the infrastructure due to a variety of challenges including contracting the work – state procurement system, bidders protest, bids 50% higher than estimated requiring the search for additional funding (successful), and addressing permitting requirements such as the lack of a fire hydrant system. This is the first installation on non federal property and is therefore under the control of the local AHJ who had no experience with hydrogen systems and the relevant codes of which there are many. The MTA bus was purposely delayed because with no hydrogen they could not be operated and we did not want them sitting idle in a harsh salt air environment. During this reporting period we are pleased to report these barriers were all overcome resulting in the successful installation of the hydrogen production and dispensing system at NELHA.**

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: Public Outreach, Significant Cost Share;
- ✓ Natural Energy Laboratory Hawaii Authority: Host Site; Site Work, Cost Share
- ✓ County of Hawaii MTA: Host Site, Bus Operator (Cost Share);
- ✓ Hawaii Volcanoes National Park: Host Site, Bus Operator;
- ✓ HCATT: Conversion of Shuttle Bus, Cost share;
- ✓ US Hybrid: Conversion of Shuttle Bus, Cost share;
- ✓ HELCO: Interested Observer, Potential Partner for Grid Analysis;
- ✓ Hydrogen Safety Panel: Design Hydrogen Safety Review;
- ✓ PNNL: First Responder Training;
- ✓ Boyd Hydrogen: Site Hydrogen Safety Review, Permitting Department Workshop.
- ✓ Proton Onsite: Electrolyzer Control System
- ✓ Aloha Petroleum: Hydrogen Delivery

Remaining Challenges and Barriers

- ✓ **Stretch budget by leveraging existing designs, partners, infrastructure;**
- ✓ **Find new sources of funding*.**

*** This US DOE component of project ended on 30 September 2015. Using other funds, HNEI has continued to operate the systems and gather additional data beyond the completion date of the US DOE portion of the project in order to develop hydrogen infrastructure to support existing and future hydrogen projects in Hawaii (A,C,H).**

Proposed Future Work

- ✓ **Commission NELHA system – July 2018**
- ✓ **Design, Install & Evaluate 10 kW FCEB export power unit in support of civil defense – July 2018;**
- ✓ **Complete HAVO system – Sept 2018**
- ✓ **Evaluate performance of the NELHA & HAVO systems;**
- ✓ **Evaluate performance of the HAVO buses air filtration system;**
- ✓ **Prepare performance reports;**
- ✓ **Prepare peer-reviewed journal papers;**
- ✓ **Operate real time NELHA site internet camera system and host on HNEI website.**
- ✓ **Support outreach activities for general public;**

Any proposed future work is subject to change based on funding levels

Technology Transfer Activities

- ✓ Applied for a utility patent on our onboard air filtration environmental sensing system developed by HNEI for the HAVO buses operating in a high air contaminant environment;
- ✓ Worked closely with Powertech to develop the hydrogen scavenging system to double the delivery of hydrogen using a hydrogen transport trailer;
- ✓ Applied the ”Lessons Learned” in this project to produce a system requirements specification for other Hawaii hydrogen projects;
- ✓ Leverage the NELHA “Hydrogen Hub” to support future equipment development R&D experiments.

Summary

Objective: Demonstrate the performance and cost benefits of grid integrated hydrogen systems.

Relevance: Electrolysis of water to produce hydrogen could contribute significantly to Hawaii's transportation 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.

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

Approach: Central site production. Distributed dispensing. Seek sites with potential for low cost renewable energy production. Validate durability and performance under sustained cyclic operation. Evaluate electrolyzer/battery hybrid designs. Deliver hydrogen to FCEV bus operators. Demonstrate performance to legislators, utilities, operators, and public;

Accomplishments: Completed system installation at NELHA. Completed conversion of MTA bus. Recertified 3 tube trailers. Developed compressor boost system to extract 90% of hydrogen from tube trailer and reduce transport cost by ~45%. Modified tube trailer with to allow computer control by boost pump system. Developed and installed10kW bus power export system to support civil defense. Developed hydrogen purity sampling system. Contracted A&E firm for HAVO system.

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

Acronyms

- ✓ BESS: Battery Energy Storage System
- ✓ CAPEX: Capital Expense
- ✓ DoD: Department of Defense
- ✓ FCEV: Fuel Cell Electric Vehicle
- ✓ H2: Hydrogen
- ✓ HAVO: Hawaii Volcanoes National Park
- ✓ HCATT: Hawaii Center for Advanced Transportation Technology
- ✓ HELCO: Hawaiian Electric Light Company
- ✓ HES: Hydrogen Energy System
- ✓ HNEI: Hawaii Natural Energy Institute
- ✓ HTT: Hydrogen Transport Trailer
- ✓ MTA: Mass Transit Agency
- ✓ NELHA: Natural Energy Laboratory Hawaii Authority
- ✓ NPS: National Park Service
- ✓ NRL: Naval Research Laboratory
- ✓ O&M: Operations and Maintenance
- ✓ ONR: Office of Naval Research
- ✓ PLC: Programmable Logic Controller
- ✓ PNNL: Pacific Northwest National Laboratory
- ✓ PV: Photovoltaic
- ✓ RFQ: Request for Quotation