2016 NELHA Energy Storage Conference

Hydrogen Energy Systems as a Grid Management Tool



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HNEI Fuel Cell/Hydrogen Research

- ***HI Sustainable Energy Research Facility (HISERF) (ONR, USDOE, HECO, NASA, Industry*)**
  - **Testing of fuel cell and battery systems for manned and unmanned vehicles**
  - **Development of advanced air filtration for FC operations in harsh environments.**

- ***Marine Corps Base Hawaii* Dual *Pressure "Fast-Fill" H2 Fueling Station (USDOE, ONR)***
  - **Basis for design of public stations**
  - **Unattended operation, 400 fills since Nov 2014**

- ***Hydrogen Energy Systems for Grid Management (USDOE, ONR, SOHI, Industry)***
  - **Demonstrate the use of electrolyzers to mitigate the impacts of intermittent renewable energy**
  - **Evaluate effect of multiple revenue streams on overall hydrogen costs.**

- ***Grid Analysis – Integration of renewables into HI grid systems***

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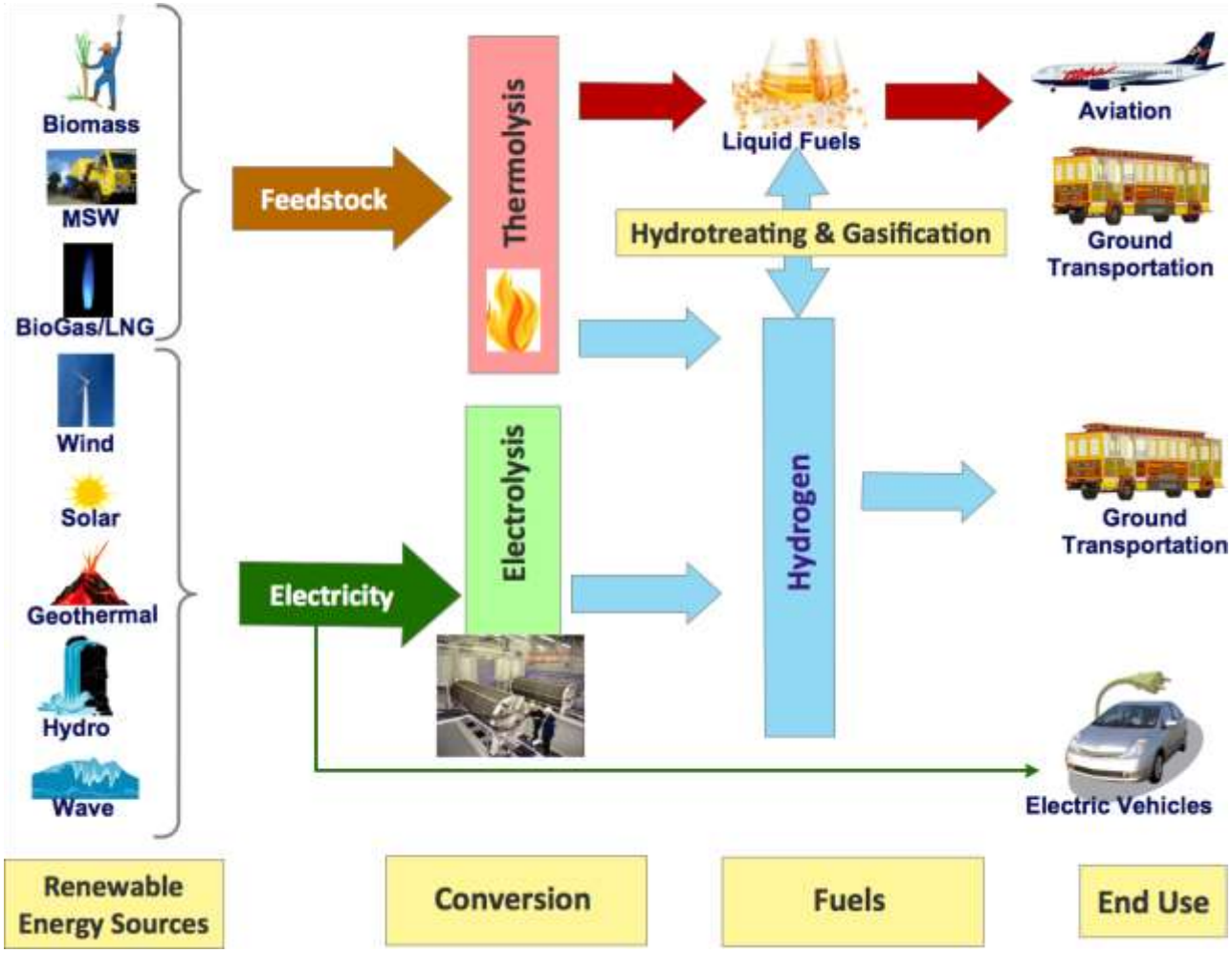
Renewable Fuels Pathways (simplified)



HI Ground Transportation ~ 500 million gpy

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 not only the load but the supply is subject to fluctuations.**
- ✓ **Grid operators attempt to stabilize the frequency by ramping power generation up/down;**
- ✓ **Battery can be a useful source/sink of power reducing the need for the utility to operate power generation at lower efficiencies and incurring higher costs;**
- ✓ **Project Thesis: An electrolyzer can be used as a variable controllable load that can be reduced/increased when other loads increase/decrease in order to maintain the total balance and the frequency stable;**

Hydrogen Energy Systems for Grid Management

Demonstrate use of electrolyzers to mitigate the impacts of intermittent renewable energy & evaluate potential to offset hydrogen costs by value-added revenue streams.

- **Use grid models/grid scale battery experiments to determine duty cycle required to provide ancillary service to the grid**
- **Characterize performance/durability of commercially available electrolyzers under dynamic conditions to provide ancillary services to grid, e.g. frequency regulation**
- **Use off-take hydrogen to fuel shuttle buses operated by County of Hawaii Mass Transit Agency, and Hawaii Volcanoes National Park (HAVO);**
- **Conduct performance/cost analysis to identify benefits of integrated system including grid ancillary services & off-grid revenue streams**

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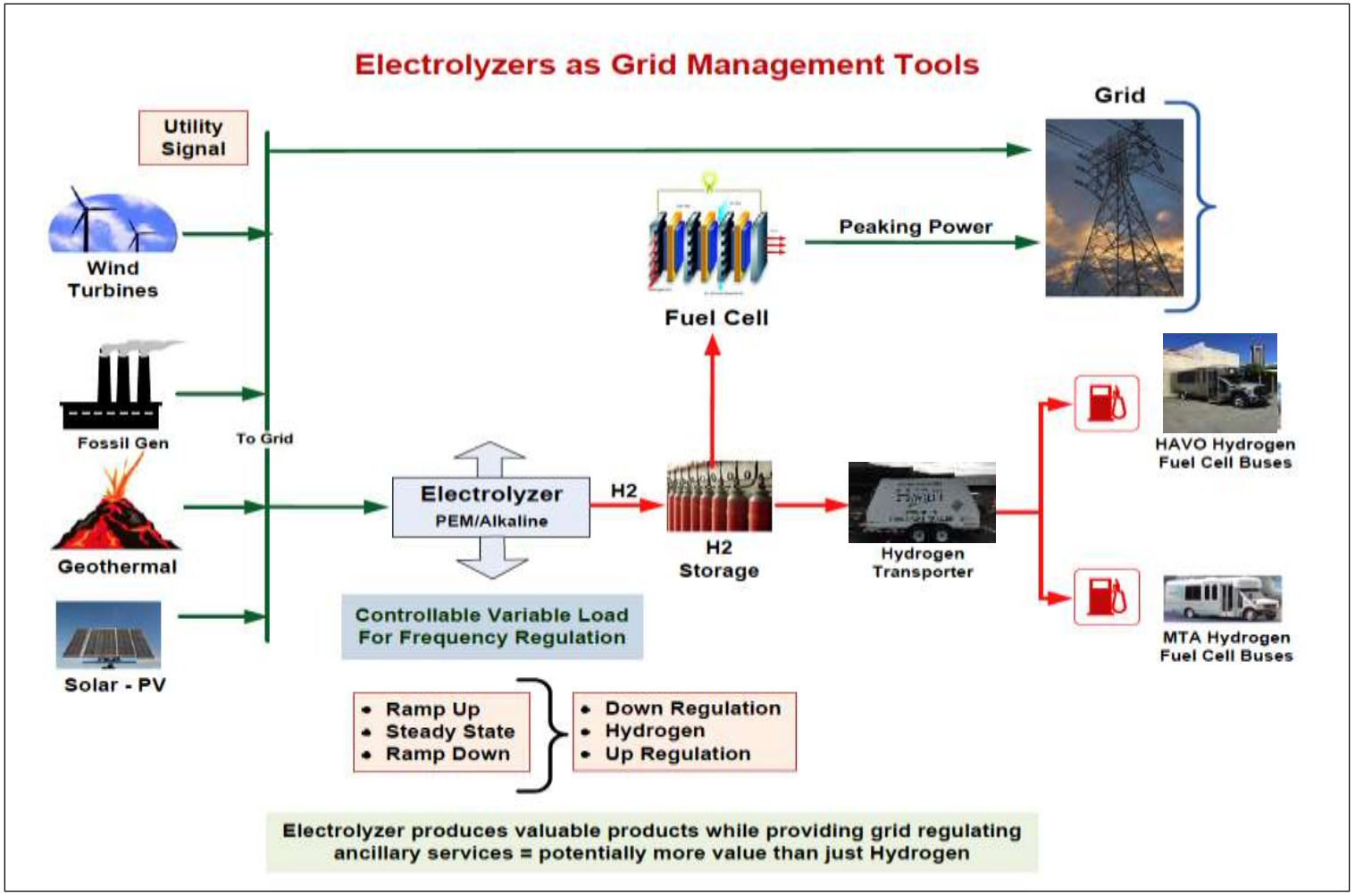
Approach



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

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High Fidelity Island Grid Models

- ✓ **HNEI & GE developed high fidelity island grid models. Invested ~ $5 million over 5 years.**
- ✓ **Address:**
  - ➢ **Operating strategies;**
  - ➢ **Renewable curtailment;**
  - ➢ **Stability with high penetration of renewables.**
- ✓ **Future work to determine potential value to grid operations:**
  - ➢ **Load shifting;**
  - ➢ **Dynamic demand response;**
  - ➢ **Storage;**
  - ➢ **eVs, and**
  - ➢ **Hydrogen.**

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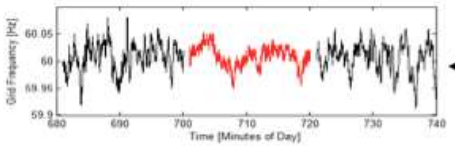
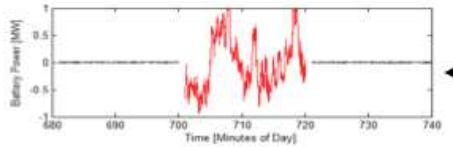
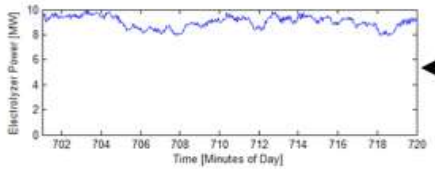
Use BESS Operation as Model for Using Electrolyzer for Grid Frequency Regulation



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



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

- **Frequency variability on 150MW grid system reduced with a 1MW, 250kwh fast BESS (*BESS separate project using Lithium-Titanate battery on HELCO Grid);**
- **Model suggests same power range as 1MW BESS can achieved with good CAPEX utilization using 10 MW-scale electrolyzer;**
- **Early operation suggests electrolyzer more appropriate for slower-acting changes;**
- **Project will investigate electrolyzer/BESS hybrid to find optimum mix of battery and electrolyzer to provide required level of grid regulation services.**

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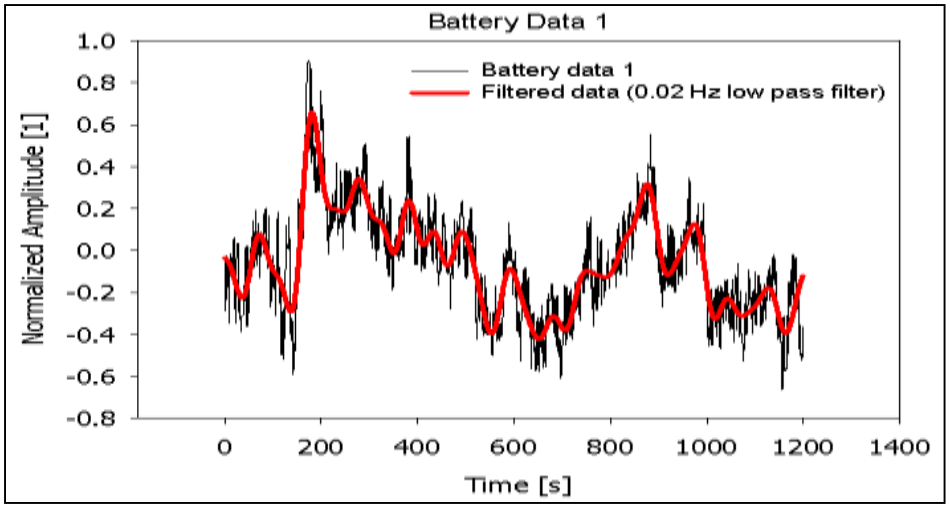
Initial Test Plan



BESS Measured Load Profile

- **Initial testing at cycle rates (ramp rates) below BESS ramp rates;**
- **Evaluate electrolyzer and controls to determine maximum allowable ramp rates;**
- **Repeated cyclic operation at "high" rates planned for durability testing;**
- **Dynamic model will be developed and used to evaluate electrolyzer/BESS hybrid performance.**

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NELHA "Hydrogen Hub"

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

Central Site Production/Distributed Dispensing

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:**
  - ➢ **Monetizing ancillary services;**
  - ➢ **Sale of hydrogen for transportation**

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NELHA Hydrogen Plant

- 65 kg/day PEM electrolyzer/compressor production system in 40 foot ISO container
- 3 hydrogen transport trailers
- 350 bar dispenser to support MTA 29-passenger shuttle bus
- Powered from HELCO grid ~ 50% renewable energy
- Automated system for unattended operation
- Remote monitoring

Completed Equipment Commissioning & Testing

Equipment under test at Powertech

- **Installed and commissioned HNEI PLC system for improved control of cycling;**
- **Completed the following:**
  - **Individual component functionality evaluation;**
  - **Electrolyzer diagnostic baseline tests. Tests at regular intervals over the 2-year duration of the project will be used to determine electrolyzer degradation over the long-term;**
  - **Conducted sweep load profile to determine operating envelope & system limits;**
  - **Tested reliability of HNEI PLC to control and operate the electrolyzer safely.**

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Big Island Buses & Hydrogen Transport Trailers

County of Hawaii Bus (1)

HAVO Buses (2)

Hydrogen Transport Trailers (3)

- **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);**
- **Hydrogen Transport Trailer carries 105 kg @ 450 bar. They will demonstrate distributed dispensing using cascade fill to 350 bar using a "Smart" dispenser.**

HAVO 350 Bar Dispensing Station

- Aloha Petroleum delivery services
- Drag & Drop “Computer Controlled” Tube Trailers.
- 350 bar Cascade Fill
- Boost compressor captures 95% of H2
- Unattended Operation
- Remote Monitoring
- Automatic shut down

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Hydrogen Energy System Analysis

HES = Electrolyzer System + Compressor + Auxiliaries

Measured power consumption and parasitic loads to determine overall system efficiency

- ✓ **Data collected by electrolyzer and HNEI PLC ;**
- ✓ **Produced 65 kg of hydrogen, compressed to 450 bar and stored in hydrogen transport trailer;**
- ✓ **Total power consumption: 79 kWh/kg**
- ✓ **Overall efficiency: 50%**
- ✓ **90% of total energy consumed by electrolyzer system;**
- ✓ **10% consumed by compressor and auxiliary loads.**

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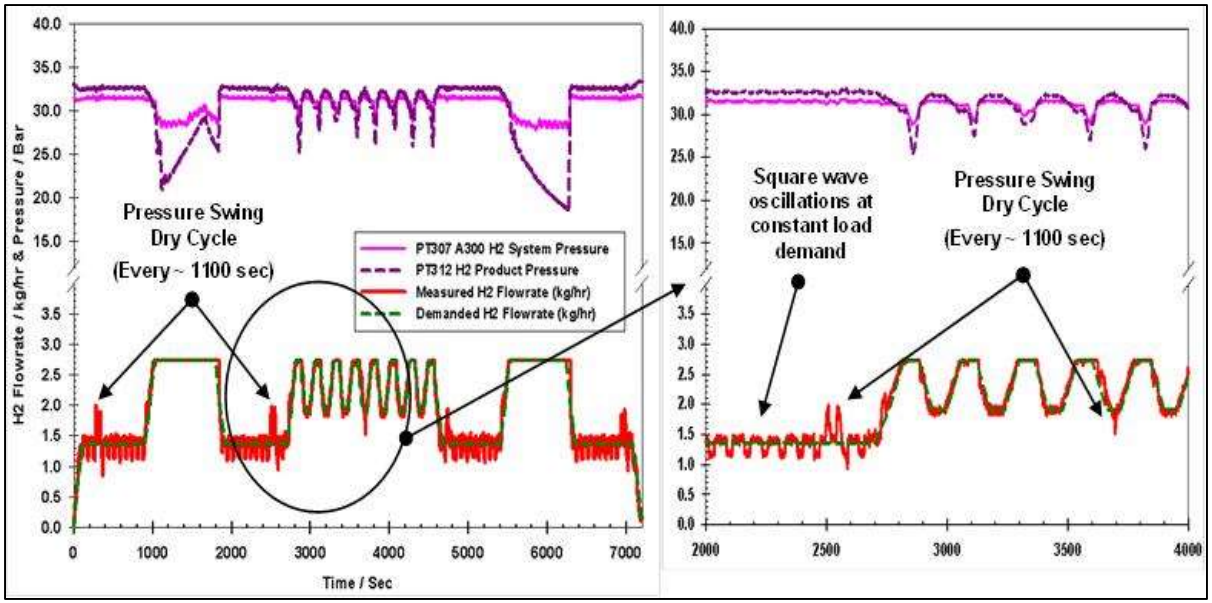
Load Profile Test Using HNEI PLC



Results of a initial load profile test using the HNEI PLC

- **Operation of the HES for hydrogen production for fueling fuel cell-battery hybrid shuttle buses was very acceptable;**
- **Use of the HES for the grid management was not suitable with the factory installed electrolyzer control system.**

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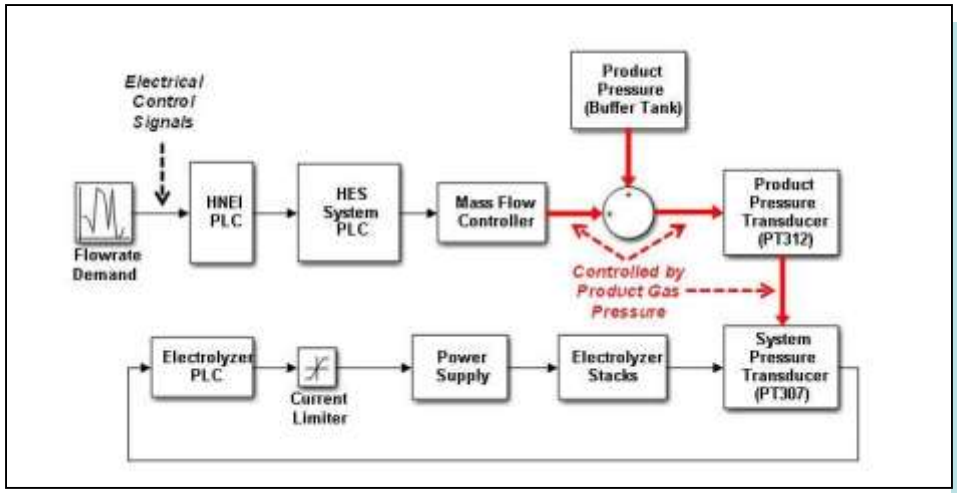
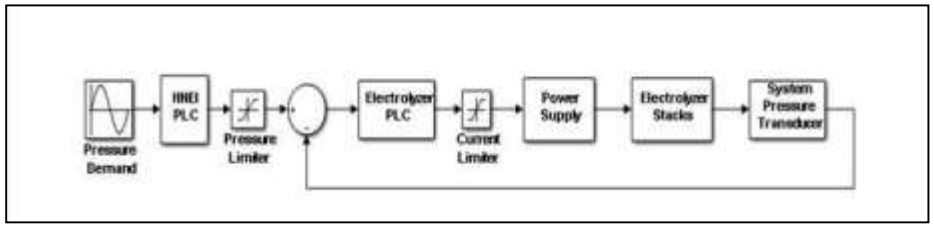
Modified Electrolyzer Control System



Original Electrolyzer Control System



HNEI Modified Electrolyzer Control System

- ✓ Electrolyzers can respond quickly to changes in load;
- ✓ Commercial hydrogen production systems not optimized for dynamic operating profiles, particularly in the areas of power conversion & controls;
- ✓ HNEI modified control system made response of the system ~10 times faster but still not fast enough to match BESS performance.
- ✓ Electrolyzer/BESS hybrid may be the solution.
- ✓ Initiated dialogue with Proton Onsite to collaborate on further control system modifications.

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, Cost Share;**
- ✓ **Natural Energy Laboratory Hawaii Authority: Host Site; Site Work**
- ✓ **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.**
- ✓ **Proton Onsite: Electrolyzer Control System**
- ✓ **Aloha Petroleum: Hydrogen Delivery**

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