

II.C.7 EVermont Hydrogen Electrolyzer Project*

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Subcontractors:

- Northern Power Systems, Waitsfield, VT
- Proton Energy Systems, Inc., Wallingford, CT

Start Date: October 1, 2004

Projected End Date: September 30, 2007

*Congressionally directed project

Objectives

- Develop advanced proton exchange membrane (PEM) electrolysis fueling station technology.
- Build and test a validation system in Vermont that utilizes renewable electricity and is capable of providing hydrogen fuel to vehicles.
- Procure a hydrogen fueled vehicle for testing and validation of the station.
- Gain experience with hydrogen as a motor fuel.
- Document vehicle performance operating on hydrogen motor fuel.

Technical Barriers

This project addresses the following technical barriers from the Hydrogen Production section of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

- (G) Capital Cost
- (H) System Efficiency
- (J) Renewable Electricity Generation Integration

Technical Targets

This project will contribute to achievement of the following DOE Hydrogen Production milestones from the Hydrogen Production section (3.1) of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

- **Milestone 7: Verify feasibility of achieving \$3.00/gge (delivered) from electrolysis.** Several activities under the EVermont project will support this milestone. An advanced lower cost, higher efficient PEM electrolysis cell stack will be field tested and evaluated. An advanced, low cost power supply will be field tested and evaluated. Time-of-day/time of year electricity pricing will be monitored to determine favorable periods for which low cost hydrogen can be produced.

Accomplishments

- Successfully tested the full-scale advanced PEM electrolysis cell stack in-house and observed 5-10% efficiency improvement.
- Successfully tested a full-scale advanced (low-cost) power supply in-house.
- Completed first version of the computer algorithm for determining price of hydrogen production considering system efficiency and time-of-day electricity pricing.
- Completed fueling station construction.
- The station was publicly dedicated in July 2006 however the station really did not begin routine operation until May 2007.
- Collected data has confirmed in-house efficiency improvements of the advanced PEM electrolyzer in field deployed operations.
- Collected data has confirmed successful and very satisfactory operation of a hydrogen powered vehicle with over 3,276 miles accumulated as fueled with hydrogen.



Introduction

EVermont was formed in 1993 as a public-private partnership of entities interested in documenting and advancing the performance of advanced technology

vehicles that are sustainable and less burdensome on the environment, especially in areas of cold climates, hilly terrain and with rural settlement patterns. Evermont has teamed with Northern Power Systems and Proton Energy Systems¹ to carry out this DOE project to utilize renewable electricity to produce hydrogen transportation fuel. Under this project, advanced PEM electrolysis technology was implemented at a fueling station site in Burlington, VT. This fueling station will serve as a test bed for the advanced technology and to demonstrate a renewable hydrogen fueling pathway for transportation applications.

Current commercial PEM electrolyzers are used in industrial applications today. The lifecycle cost of those systems needs to be improved in order to gain acceptance into future hydrogen vehicle fueling systems. In this project, a focus was placed upon advancing the state-of-the-art of the cell stack and the power supply. In addition, an effective method for allowing operation in the extreme cold climate of Vermont was devised and implemented. A hydrogen-fueled vehicle was procured and operated as part of this project.

Approach

The approach encompasses research and development aspects for electrolysis-based hydrogen fueling systems and fueling system demonstration.

- An advanced PEM electrolysis cell stack and advanced power supplies were tested in-house, and then incorporated into the fueling station.
- A design to allow for outdoor installation of the PEM electrolyzer in extreme cold weather was devised and implemented.
- In-house testing of the entire fueling station was completed, followed by final commissioning in Burlington, VT.
- Performance of individual subsystems (cell stacks, power supplies) continues to be monitored as well as performance of the overall system, including the usage of renewable electricity.
- Procurement and operation of a hydrogen-fueled vehicle.

Results

Cell Stack & Power Supplies

- The advanced cell stack was tested in-house and was deployed to the field in May 2006 (see Figure 1).
- The advanced power supplies have undergone several months of successful testing and were also deployed into the field in May 2006.

¹ Northern Power Systems and Proton Energy Systems were acquired by Distributed Energy Systems, and now go by this name.



FIGURE 1. Proton Energy’s Cell Stacks On Site (the Advanced 20/20 Cell Stack is in the Middle)

- Field observations of the energy consumption of the three cell stacks confirm the benefits of the advanced design. Figure 2 represents one observation from routine in-use operation confirming the energy advantage of the advanced cell stack design.
- The cold-weather heating package was tested in-house and in the field over the winter 2006/2007.
- The site was permitted, constructed and commissioned.
- The station has produced approximately 75 kilograms of hydrogen since October, 2006.

H₂ Hybrid

- A Toyota Prius was procured and converted by Quantum Technologies to run on hydrogen.
- The vehicle’s performance has been qualified and compared to that of a unmodified Prius (Figure 3).
- The vehicle has accumulated 3,276 miles on hydrogen fuel.
- The H₂ hybrid vehicle performance, as documented in Figure 4, has been determined to be comparable to that of an unmodified Prius.

Cell-Stack	EM1	EM2	EM3
Current	158	158	156
Voltage_1	75	70	75
Voltage_2	76	69	77
Average Volts	75.5	69.5	76
Power, Watts	11,929	10,981	11,856
Delta EM2	8.6%		8.0%

FIGURE 2. Analysis of Cell Stack Energy Consumption



FIGURE 3. H₂ Hybrid and Conventional Prius Performance Testing at Knapp Airport, Berlin, VT

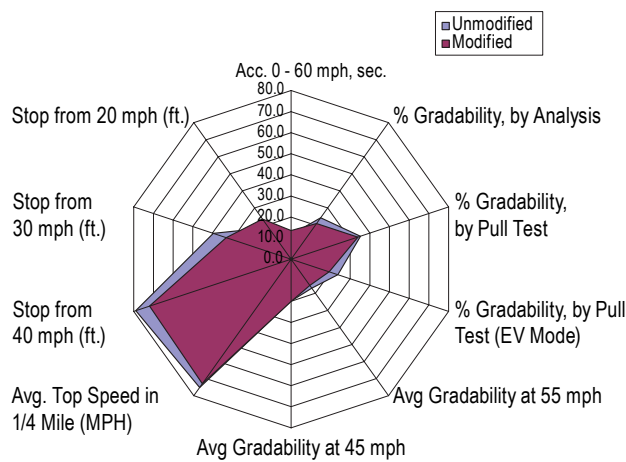


FIGURE 4. Comparison of Measured Performance of H₂ Hybrid and Prius

- The vehicle was placed in routine fleet operations with the City of Burlington, Department of Public Works on May 4, 2007.
- A method of collecting time-series fuel consumption data for the H₂ hybrid has been developed. This methodology relies upon sensors fitted on the vehicle for operation and the vehicle’s onboard diagnostic system. An example of these data are provided in Figure 5.

Conclusions and Future Directions

Technology development of the advanced PEM electrolysis cell stack and power supplies was completed successfully. Field verification of efficiency benefits were initially documented. The H₂ hybrid vehicle was qualified and placed in service. Routine fleet operations of vehicle and fueling station are ongoing.

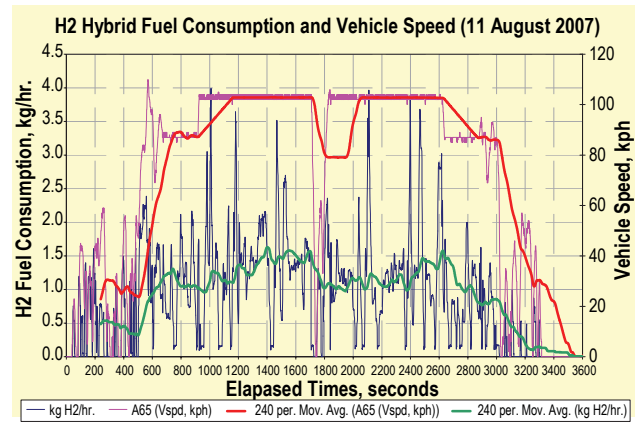


FIGURE 5. Time Series Fuel Consumption and Vehicle Speed Data

Many design improvements have been incorporated in next offerings of the hydrogen generator. Equipment has moved from prototype to the standard product offering.

Preliminary investigations are being made into the implications of connecting hydrogen created at this station from renewable wind energy with an adjacent facility for fast-fill of natural gas powered buses in order to produce a fuel blend of hydrogen and natural gas.

Special Recognitions & Awards/Patents Issued

1. Applying for patent “COLD WEATHER HYDROGEN GENERATION SYSTEM AND METHOD OF OPERATION” – in August 2006.

FY 2006/07 Publications/Presentations

Presented educational and project information to the following groups:

- Department of Public Works Commission
- Fire marshal, Vermont regional fire manager and other fire officials
- Burlington Electric Department
- City Council Transportation, Energy and Utilities Committee
- Burlington Conservation Board
- Burlington Development Review Board
- Public, Tour de Sol
- Public, SCCA Green Car Rally
- Public, Vermont Council of World Affairs, Burlington Energy Day
- 2nd annual New York New Energy Symposium and Hydrogen Expo
- EVS-23 [battery/hybrid/fuel cell] Symposium –Sustainability: The Future of Transportation; December, 2007. Paper accepted and in development.