VII.A.4 Fuel Cell Hybrid Electric Delivery Van Project

Jason Hanlin
Center for Transportation and the Environment
730 Peachtree Street, Suite 760
Atlanta, GA 30308-1209
Phone: (404) 808-6489
Email: Jason@cte.tv

DOE Manager: Jason Marcinkoski
Phone: (202) 586-7466
Email: Jason.Marcinkoski@ee.doe.gov

Contract Number: DE-EE0006523/0002

Subcontractors:

- Hydrogenics USA, San Diego, CA
- United Parcel Service (UPS), Sandy Springs, GA
- Unique Electric Solutions (UES), Stony Brook, NY
- University of Texas at Austin Center for Electromechanics, Austin, TX
- Valence Technology, Austin, TX

Project Start Date: July 15, 2014
Project End Date: November 30, 2020

Overall Objectives

- Increase the zero-emission driving range and commercial viability of medium-duty electric drive trucks.
- Phase 1: Develop a fuel cell hybrid electric delivery van and validate its design and construction through in-service operation.
- Phase 2: Build the Phase 1 delivery van at precommercial volume (up to 16 vehicles) and perform at least 5,000 operation hours of in-service demonstration.
- Develop an Economic/Market Opportunity Assessment for medium-duty fuel cell hybrid electric trucks.

Fiscal Year (FY) 2016 Objectives

- Complete vehicle design.
- Complete subcontractor change.
- Secure complete project funding.
- Coordinate hydrogen fueling infrastructure at demonstration sites and investigate fueling issues associated with medium-duty vehicles.

Technical Barriers

This project addresses the following technical barriers from the following sections of the Fuel Cell Technologies Office Multi-Year Research, Development, and Demonstration Plan.

Technology Validation

(A) Lack of Fuel Cell Electric Vehicle and Fuel Cell Bus Performance and Durability Data

Market Transformation

(D) Market uncertainty around the need for hydrogen infrastructure versus timeframe and volume of commercial fuel cell applications

(F) Inadequate user experience for many hydrogen and fuel cell applications

Technical Targets

This project directly addresses Market Transformation Section 3.9.4 Sub-Program Targets. This project lays out a very specific and rational pathway for the introduction of fuel cell technologies into the medium-duty vehicle market. The project has a technology validation phase and a follow-on deployment of precommercial volumes of the vehicles. The project is built upon the initial structure that DOE prescribed in the Funding Opportunity Announcement and is augmented by the active participation and guidance of a major commercial fleet operator, UPS. UPS operates 46,000 medium-duty vehicles worldwide. Further, the vehicles will be deployed in California to take advantage of that state's focused growth of fueling infrastructure and desire to deploy zero-emission vehicles. The Center for Transportation and the Environment has coordinated with station providers early in the project in order to identify and overcome fueling station barriers for this emerging application of fuel cell technologies, such as the limitation of J2601 fueling protocol described below. This project further leverages the resources and support of the State of California. The project team has also focused on upfront design to ensure that (1) selection of the fuel cell size will take advantage of volume growth from other applications and markets, and (2) the design will meet the needs of our commercial fleet operator by matching the performance of incumbent technologies, while meeting the range requirements for over 97% of delivery van duty cycles.

FY 2016 Accomplishments

- Resolved outstanding administrative issues and executed a contract modification with DOE, which enables the

project team to resume technical activity after being "on-hold" for much of FY 2016.

- Secured $980,000 in additional project cost share, which makes the Phase 1 budget whole and enables the team to perform the nonrecurring engineering, project management, design, and build work required to deploy six vehicles in Phase 2.
- Updated vehicle performance models and repeated simulation activity to capture most recent mass estimates and the impact of utilizing a switch-reluctance motor. A trade study of component sizes and specifications was performed. The team ensured that components meet technical requirements and align with commercialization strategy (e.g., utilize off-the-shelf systems and minimize custom solutions).
- Evaluated thermal management strategy and estimated battery thermal characteristics under simulated loads.
- Continued vehicle solid modeling and component layout and packaging activities. Involved the fleet operator (UPS) during the design phase to ensure the van aligns with the end user's expectations and to help promote commercial acceptance of final product.

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INTRODUCTION

Parcel delivery van fleets are currently dominated by diesel and compressed natural gas powered Class 3–6 trucks. In recent years, some parcel delivery services have integrated battery–electric trucks into their fleet; however, these battery–electric vehicles have been unable to match the performance of existing delivery vans and their limited range significantly impacts deployment strategy. The intent of this project is to develop a hydrogen fuel cell hybrid electric van that provides fleet operators with a zero-emission vehicle capable of meeting route range requirements while matching the performance characteristics of its existing fleet vehicles. According to Fleet DNA Project Data compiled by the National Renewable Energy Laboratory, a vehicle with a 125-mi range will meet 97% of Class 3–6 daily delivery driving distances [1]. Meeting this 125-mi range threshold will increase the attractiveness of zero-emission trucks to fleet operators and increase their commercial viability.

APPROACH

This project aims to develop and demonstrate a hydrogen fuel cell hybrid electric van with a 125-mi operational range and validate the vehicle through in-service deployment in a California UPS fleet. This project has two phases:

- Develop a fuel cell hybrid electric delivery van and validate its design and construction through in-service operation.
- Build the Phase 1 delivery van at precommercial volume (up to 16 vehicles) and perform at least 5,000 operation hours of in-service demonstration.

During Phase 1, real-world delivery van route data is collected to define the expected duty cycle requirements. All potential fuel cell hybrid electric van powertrain configurations are then modeled and simulated on the duty cycles to assess vehicle performance and aid final design. Trade studies (including cost and projected costs at high volumes) are accomplished and vehicle components are then down-selected and the physical layout is completed. The first delivery van can then be built and validated through in-service operation. If the delivery van meets Phase 1 performance requirements, the project team will build and deploy up to 16 additional vans in Phase 2. All of the vans will be demonstrated in California. Vehicle performance data during the demonstration periods will be collected and provided to the National Renewable Energy Laboratory's National Fuel Cell Technology Evaluation Center for analysis.

The project team benefits from having members with extensive hydrogen fuel cell experience, including the Center for Electromechanics and Hydrogenics, and one of the largest medium-duty truck fleet operations in the world, UPS. UPS has deployment experience with delivery vans powered by various fuels, including gasoline, diesel, compressed natural gas, and battery–electric. This experience gives them a unique perspective on the commercial viability of alternative-fueled vehicles and their project contributions are invaluable. Project funding is provided by the DOE, the California Energy Commission, and the South Coast Air Quality Management District. UPS is providing cost share during the demonstration periods by supplying operation, maintenance, and fueling costs.

RESULTS

The team's modeling activity and component trade study showed that a 32-kW fuel cell module, 49-kWh battery energy storage, and 10–15 kg of hydrogen are required to meet the 125-mi driving range objective on actual UPS delivery routes. The team also simulated the van's performance on the Hybrid Truck User's Forum Parcel Delivery drive cycles. In all simulation scenarios, the team found that drive cycles created from real-world data were more strenuous than available industry-standard drive cycles.

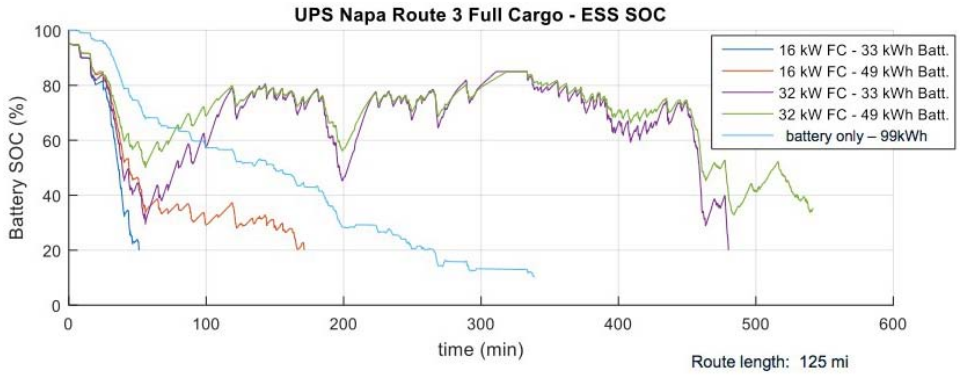
Thermal response of the battery pack varies with pack size and configuration. The 49-kWh battery pack has more favorable thermal response characteristics than a 33-kWh system, which was also being considered. Onboard hydrogen

storage should be maximized, but is limited by physical packaging and off-the-shelf tank options. The team has performed the design and layout work required to fit 350 bar hydrogen tank cylinders with 10-kg capacity on the van, but the project team learned that 700 bar tank cylinders suitable for integration with medium-duty vehicles are not currently commercially viable. Development of Type 4 700 bar tanks, which would allow 15 kg of hydrogen to be stored onboard, will be reevaluated for vehicles in Phase 2 of the project.

The proposed propulsion system configuration will allow the van to outperform existing battery-electric vans in UPS' fleet, as shown in the example simulation results in Figure 1. With 15 kg of hydrogen on board, the simulated fuel cell van operates for the full Napa route and drives 125 mi. The battery–electric van cannot reach 400 min of operation and only travels 70 mi.

After repeating the modeling activity, the team updated the vehicle specifications, which includes the following:

Physical Specifications:	Battery System:
Vehicle Chassis – Navistar International 1652SC 4X2	Chemistry – LiFeMgPO4
Maximum Speed – 65 mph	49 kWh
Maximum Range – 125 mi	Configuration – 16s3p
Acceleration (0 to 60 mph) – 26 s at 19,500 lb	1,500 cycles / 5 yr
GVW – Class 6 (23,000 lb)	Fuel Cell:
Wheel Base – 176 in	Rated Power – 32 kW continuous
Capacity – 970 ft^3	Peak Efficiency – 55%
	Hydrogen Storage:
	Capacity – 9.78 kg
	Pressure – 350 bar



SOC – State of charge; FC – Fuel cell; Batt. – Battery

FIGURE 1. Simulated performance of fuel cell and battery–electric vans on UPS delivery route

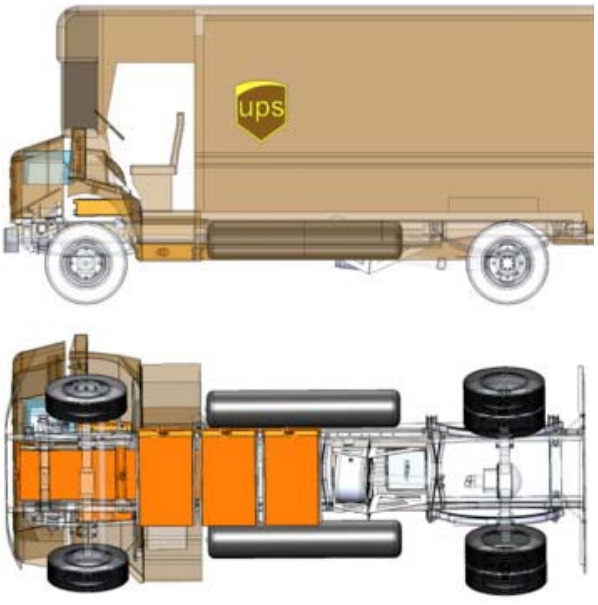


FIGURE 2. Physical layout and component packaging with van body

Initial solid models of the van's physical layout and component packaging are shown in Figure 2.

CONCLUSIONS AND FUTURE DIRECTIONS

The Fuel Cell Hybrid Electric Delivery Van project is utilizing team member experience with hydrogen fuel cell technologies, alternate fuel vehicle fleet familiarity, and stakeholder feedback to develop commercially viable zero-emission medium-duty trucks. The team has developed:

- Vehicle and component specifications to promote commercial acceptance.
- Component selection to ensure performance on real-world delivery duty cycles.
- Solid models of major components within the vehicle body.
- Strategy to ease UPS fleet acceptance and fueling procedures.

Future work includes:

- Completing safety hazard analysis with support from the Hydrogen Safety Panel.
- Coordinating fueling availability and continue coordinating the development of medium-duty hydrogen fueling protocol.
- Completing final design for the vehicle.
- Building and commissioning initial van design.
- Validating prototype van through in-service operation.
- Building final van design at precommercial volume (up to 16 vehicles).
- Training and educating end user fleet operations personnel.
- Deploying and supporting vans in UPS California fleets.
- Collecting and evaluating in-service data during demonstration period.
- Developing an Economic/Market Opportunity Assessment for the vehicles.

FY 2016 PUBLICATIONS/PRESENTATIONS

1. J. Hanlin, "Fuel Cell Hybrid Electric Delivery Van Project," presented at the DOE Annual Merit Review, Washington, DC, June 6–10, 2016.

REFERENCES

1. Walkowicz, K.; Kelly, K.; Duran, A.; Burton, E. (2014). *Fleet DNA Project Data*. National Renewable Energy Laboratory. http://www.nrel.gov/fleetdna