Fuel Cell Hybrid Electric Delivery Van

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Subcontractors:
- Hydrogenics, San Diego, CA
- United Parcel Service, Sandy Springs, GA
- Unique Electric Solutions, Stony Brook, NY
- The University of Texas at Austin Center for Electromechanics, Austin, TX
- Lithium Werks, Austin, TX

Project Start Date: July 15, 2014
Project End Date: April 30, 2022

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 pre-commercial volume (up to 15 additional 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) 2019 Objectives

- Test and validate the vehicle according to DOE contractual specifications.
- Complete pre-deployment training and education at the demonstration site in West Sacramento, California.
- Begin vehicle demonstration by deploying it into United Parcel Service (UPS) revenue service.

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[1]:

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.

Contribution to Achievement of DOE Market Transformation Milestones

This project directly addresses subprogram targets from the Market Transformation section of the Fuel Cell Technologies Multi-Year Research, Development, and Demonstration Plan.[1] It provides a 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 a pre-commercial volume of the vehicles in parcel delivery service. 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. Furthermore, the vehicles will be deployed in California to take advantage of the 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

[1] https://www.energy.gov/eere/fuelcells/downloads/fuel-cell-technologies-office-multi-year-research-development-and-22

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 2019 Accomplishments

- Completed vehicle acceptance testing and specification validation.
- Delivered vehicle to the UPS Customer Center in West Sacramento to close out Task 1.
- Completed operator, maintenance, fueling, and first responder training to close out Task 2.
- Began Phase 1 demonstration in West Sacramento for three months and continued demonstration in Gardena for an additional three months.
- Reported operational data to the National Renewable Energy Laboratory (NREL) for analysis.
- Developed and maintained a vehicle activity tracking log, which includes issues, root cause, resolutions, and other pertinent information to inform Phase 2 design updates.
- Executed a grant agreement with the California Air Resources Board (CARB) for Zero- and Near Zero-Emission Freight and Facilities program award, which accounts for the remaining project funds necessary to carry out the full project scope of the work.
- Completed engineering design updates that finalized component selection and vehicle-level packaging for Phase 2 vehicles.
- Completed the manufacturing plan, which details major bill of materials, component specifications, procurement timelines, build plan and schedule, detailed build instructions, quality assurance and other control procedures, product version control methodology, and deviation communication protocol.

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 fleets; 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 NREL, a vehicle with a 125-mile range will meet 97% of Class 3–6 daily delivery driving distances [1]. Meeting this 125-mile 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-mile operational range and validate the vehicle through in-service deployment in a California UPS fleet. This project has two phases:

1. Develop a fuel cell hybrid electric delivery van and validate its design and construction through in-service operation
2. Build the Phase 1 delivery van at pre-commercial volume (up to 15 additional vehicles) and perform at least 5,000 operation hours of in-service demonstration.

During Phase 1, real-world delivery van route data are 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 15 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 NREL's National Fuel Cell Technology Evaluation Center for analysis.

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

RESULTS

During FY 2019, the project team completed acceptance testing and specification validation, published the operations manual, delivered the vehicle to West Sacramento, began the demonstration period, developed and maintained a vehicle activity tracking log, upgraded the DC/DC converter, executed the grant agreement with CARB to complete the full Phase 2 scope of work, completed both the final engineering design and manufacturing plan, and transferred the vehicle to Gardena, where the Phase 1 demonstration will conclude.

After receiving the vehicle in West Sacramento, the project team completed performance troubleshooting and a test fueling at the local Linde hydrogen refueling station to validate vehicle operability. Unique Electric Solutions conducted operations and maintenance training with UPS drivers, mechanics, and supervisors. The Center for Transportation and the Environment led fueling training in coordination with Linde to ensure the drivers and supervisors received hands-on experience. The vehicle was put into revenue service on February 8, 2019.

Figure 1. UPS operator training led by Joe Ambrosio of Unique Electric Solutions

During its first day in operation, the vehicle's fuel cell DC/DC converter failed, which resulted in loss of fuel cell power. Unique Electric Solutions investigated the root cause, repaired the DC/DC converter, and prepared the vehicle to re-enter service in April; however, the Linde station was only providing partial fills, which prevented the vehicle from re-entering service. The project team worked with the dispenser provider so that the station could provide full fills, but one of the on-board hydrogen detectors located above the cylinders was

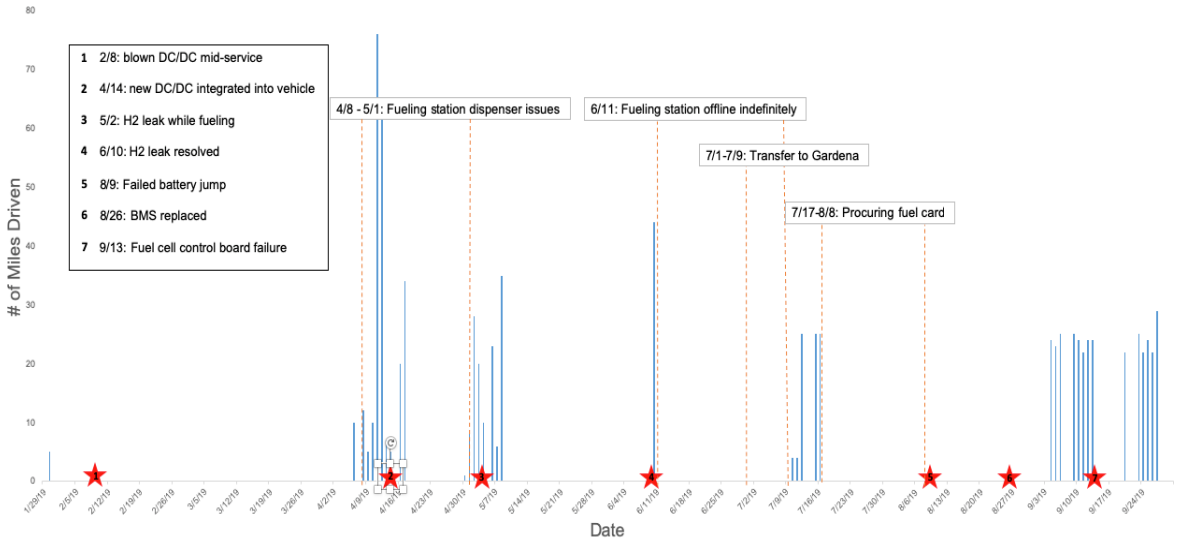
triggered during a high-pressure fill. The seals in the hydrogen system were not rated for low enough temperatures to accommodate the pre-cooled hydrogen at high pressure. These seals were replaced but could not be validated due to the West Sacramento station closing for an extended period. The vehicle was transferred to Gardena in order to demonstrate the truck in southern California and to provide consistent fueling at the Shell station in Torrance.

Figure 2. The vehicle fueling at the Linde station in West Sacramento

The vehicle arrived in Gardena in early July, and the project team completed a second round of UPS training and fueling tests, which validated successful fueling with the new seals. The vehicle operated for several days without issue but was unable to fuel until UPS procured a fueling card to fuel off-site. After additional downtime due to driver continuity issues, the vehicle was scheduled to return into service in early August, but UPS noticed that the driver display read 0% state of charge due to a discharged 12-V battery caused by the extended downtime. UPS attempted to jump the vehicle 12-V battery with another 12-V battery, and the brief overcurrent damaged battery management system control boards. Unique Electric Solutions replaced the battery management system control boards and the 12-V battery and added appropriate signage to the 12-V battery as a preventative measure. Once the issue was corrected, both local fueling stations were offline, so the vehicle was unable to fuel and did not return into service until early September.

Figure 3. Delivering packages at a nearby mall in Gardena

The vehicle returned to service in September as expected and operated without fault for two weeks. During a service run, the fuel cell stopped sending controller area network communications, which resulted in a week of downtime. The vehicle completed its route, and the faulty fuel cell control board was quickly replaced. The vehicle has been in continuous service since September 20 and all gathered data have been submitted to NREL for analysis. Phase 1 demonstration activity to date is summarized in Figure 4. The vehicle will continue to operate in revenue service past the demonstration end date in mid-October and may be used to test the next-generation fuel cell DC/DC converter ahead of Phase 2.



BMS – battery management system

Figure 4. Phase 1 demonstration overview

Two tasks from Phase 2 were moved into Phase 1 and completed: engineering design updates and the manufacturing plan. Unique Electric Solutions finalized their Phase 2 vehicle design in collaboration with the project team. The updated design includes component selection and vehicle-level packaging and incorporates lessons learned from the Phase 1 demonstration. The manufacturing plan for the 15 Phase 2 vehicles was completed and includes a major bill of materials, component specifications, procurement timelines, build plan and schedule, detailed build instructions, quality assurance and other control procedures, product version control methodology, and deviation communication protocols. Additionally, the vehicle modeling parameters have been updated to reflect the actual vehicle performance and to be a resource for future vehicle projections. Phase 2 simulations using these parameters will be completed in October.

CONCLUSIONS AND UPCOMING ACTIVITIES

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:

- Completed vehicle acceptance testing
- Delivered the vehicle to West Sacramento, where UPS operated the vehicle, and then delivered the vehicle to Gardena, where UPS is currently operating the vehicle
- Trained UPS operations and maintenance personnel and local first responders
- Updated the vehicle design based on lessons learned during the demonstration
- Executed contract with CARB for remaining funds required to build and demonstrate 15 additional Phase 2 vehicles

- Coordinated hydrogen fueling availability and compatibility with Shell in Gardena
- Collected and evaluated operating data during deployment.

Future work includes:

- Conclude Phase 1 demonstration period on October 12, 2019
- Test the next-generation DC/DC converter on the Phase 1 prototype vehicle
- Complete DOE go/no-go
- Complete Phase 2 vehicle modeling and simulation
- Build 15 additional fuel cell hybrid electric delivery vans
- Coordinate hydrogen fueling availability at deployment site(s)
- Deploy and support 15 vans into UPS California fleets
- Collect and evaluate operating data during deployment

FY 2019 PUBLICATIONS/PRESENTATIONS

1. Jason Hanlin, "Fuel Cell Hybrid Electric Delivery Van Project." Presented at the 2019 DOE Hydrogen and Fuel Cells Program Annual Merit Review and Peer Evaluation Meeting, Crystal City, VA, May 1, 2019.
2. Maria Gallucci, "UPS to Deploy Fuel Cell/Battery Hybrids as Zero-Emission Delivery Trucks," *IEEE Spectrum*, August 24, 2018, accessed November 19, 2018, https://spectrum.ieee.org/green-tech/fuel-cells/ups-to-deploy-fuel-cellbattery-hybrids-as-zeroemission-delivery-trucks.

REFERENCES

1. "Fleet DNA Project Data," National Renewable Energy Laboratory, http://www.nrel.gov/fleetdna.