X.2 Ground Support Equipment Demonstration

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Project Start Date: January 2013
Project End Date: December 2017

Overall Objectives

- Create a hydrogen fuel cell-based solution for cargo tractors (airport vehicle) that is cost-competitive and more energy-efficient compared to incumbent internal combustion engine-powered alternatives.
- Enable airport end users to accomplish daily tasks with a hydrogen fuel cell solution while reducing consumption of gasoline and diesel fuels, reducing U.S. demand for petroleum.
- Demonstrate lower carbon emissions with fuel cells.
- Demonstrate a value proposition that shows decreased energy expenditures when compared to diesel-powered airport vehicles.

Additional program objectives are shown in Table 1.

Fiscal Year (FY) 2017 Objectives

- Second year of demonstration.
- Incorporate improvements to design and service.
- Vetting the value proposition.
  - Vetting the assumptions.
  - Diesel fuel consumption, idle time, and annual operating hours.
  - Diesel tractor maintenance, specifically starters, brakes, and oil changes.
  - Diesel maintenance interval.
  - Fuel cell maintenance.
- System and tractor improvements.
  - Optimizing efficiency (lower kWh usage per shift).
  - Optimizing regenerative braking (recover maximum energy).
- Run time with plug stack-based system.
  - Four seasons of operation, precipitation, temperature fluctuations, etc.
  - Long-term durability, effects of months of shock and vibration.
  - Expand the fleet to full 15 tractors (nine as of late April 2017).
  - Increased usage by FedEx operators (training required).
- Service: feedback from FedEx service technicians.
  - FedEx technicians performing preventative maintenance.
  - Integrate into FedEx standard operating procedure and management system.

TABLE 1. Program Objectives

DOE Project Objectives	Plug Power–FedEx Project Expectations
Reduce petroleum consumption	Each tractor uses ~2 gal/h. Total tractor run time of 15 tractors over 2 years will be upwards of **175,200 gallons of diesel fuel reduced**.
Reduce emissions at airports	At 9.8 kg CO_2 per gallon of diesel, there will be upwards of **1,717 metric tonnes of CO_2 eliminated at airports**.
Operate 10 h/day and 5,000+ h	Tractor operation occurs during two shifts: day (10 AM–2 PM) and night (10 PM–2 AM). The total clock day is 10 AM–2 AM (16 hours). **Actual tractor activity is 8 h/day. Total run time of 15 tractors over 2 years will be upwards of 87,600 fleet hours.**
Drawbar capacity 3,000 to 6,000 lb	The tractor will be able to tow 4 FedEx containers each weighing 40,000 lb. The corresponding **drawbar capacity of the fuel cell-powered tractor is 5,000 lb**.
Accelerated development of fuel cell-powered GSE	**Fleet of 15 80 V fuel cell systems in real world application gaining significant field experience while allowing a premier tractor end user to evaluate for larger deployments.**

Technical Barriers

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

(B) High hydrogen fuel infrastructure capital costs for Polymer Electrolyte Membrane (PEM) fuel cell applications

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

In addition, the project addresses the following specific technology barriers.

- Adapt GenDrive architecture to tractor voltage/power requirements.
- Weatherproof for outdoor application.

Technical Targets

- Power: capable of 5,000 lb drawbar capacity
- Availability: >80%
- Run time: >1 shift
- Reliability (mean time between failures): >100 h
- Speed rating: 10 mph
- Outdoor operation: no non-recoverable issues
- Hydrogen fills: 350 bar

FY 2017 Accomplishments

- Completed first year of demonstration.
- Decision to move away from third party stack (16 stack failures averaging 61 h life) and build a new design with Plug Power stacks for the second year of the demonstration.
  - Note: stack issues included hard failures requiring refurbishment, inability to start, and excessive purging.
- Incorporated design improvements into the new design to optimize serviceability.
- Summarized learning from Year 1.
  - Tractor handles application load.
  - Operating outdoor 24 hours per day, seven days per week is not a problem.
  - Weatherproofing strategy works well; no water ingress.
  - Air filtration protects the system from airport hydrocarbon emissions.
  - Tractor can operate worst route for full shift without needing to refuel.
  - Handful of components that had a drastic effect on reliability.
- First year evaluation.
  - Power: capable of 5,000 lb drawbar capacity – yes
  - Availability: >80% – no (initially 70% but dropped due to accelerating stack failures)
  - Run time: >1 shift – yes
  - Reliability (Mean time between failures): >100 h – no (98 h)
  - Speed rating: 10 mph – yes
  - Outdoor operation: no non-recoverable issues – yes
  - Hydrogen fills: 350 bar – yes
- System redesign with Plug Power stacks (Figure 1).
- Redesigned system completed and tested.

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INTRODUCTION

This project deploys 15 fuel cell-powered units for two years at FedEx Express's busiest airport. The project is planned for two phases. The first is a one year development phase where Plug Power develops, builds, and tests the 80 VDC (20 kW) fuel cell system for the cargo tractor application. The second is a two-year demonstration where a fleet of cargo tractors are integrated into Charlatte CT5E electric cargo tractors and deployed at the FedEx locations under real-world conditions. The fuel cell fleet is fueled by a GenFuel hydrogen compression, storage, and dispensing solution.

APPROACH

Plug Power designed an 80 VDC fuel cell system as a drop-in-place replacement of an electric Charlatte tractor (Figure 2).

Hydrogen is supplied to the tractors via GenFuel hydrogen infrastructure, which provides onsite hydrogen at 350 bar dispensed directly to the fuel cell in the tractor (Figure 3).

- Definition of requirements – complete
- Alpha prototype – complete
- Cargo tractor beta builds – complete
- Cargo tractor testing and certification – complete

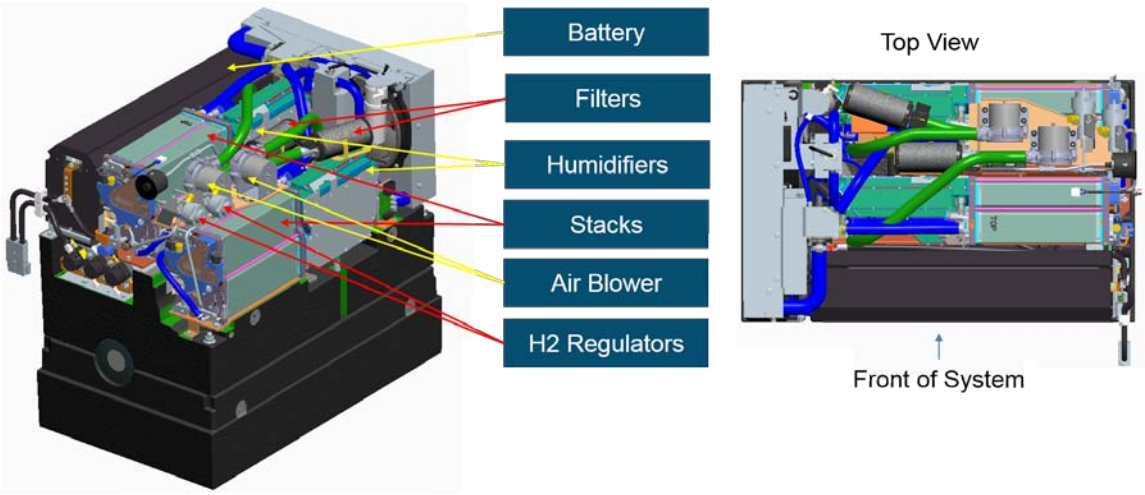

FIGURE 1. System redesign with Plug Power stacks

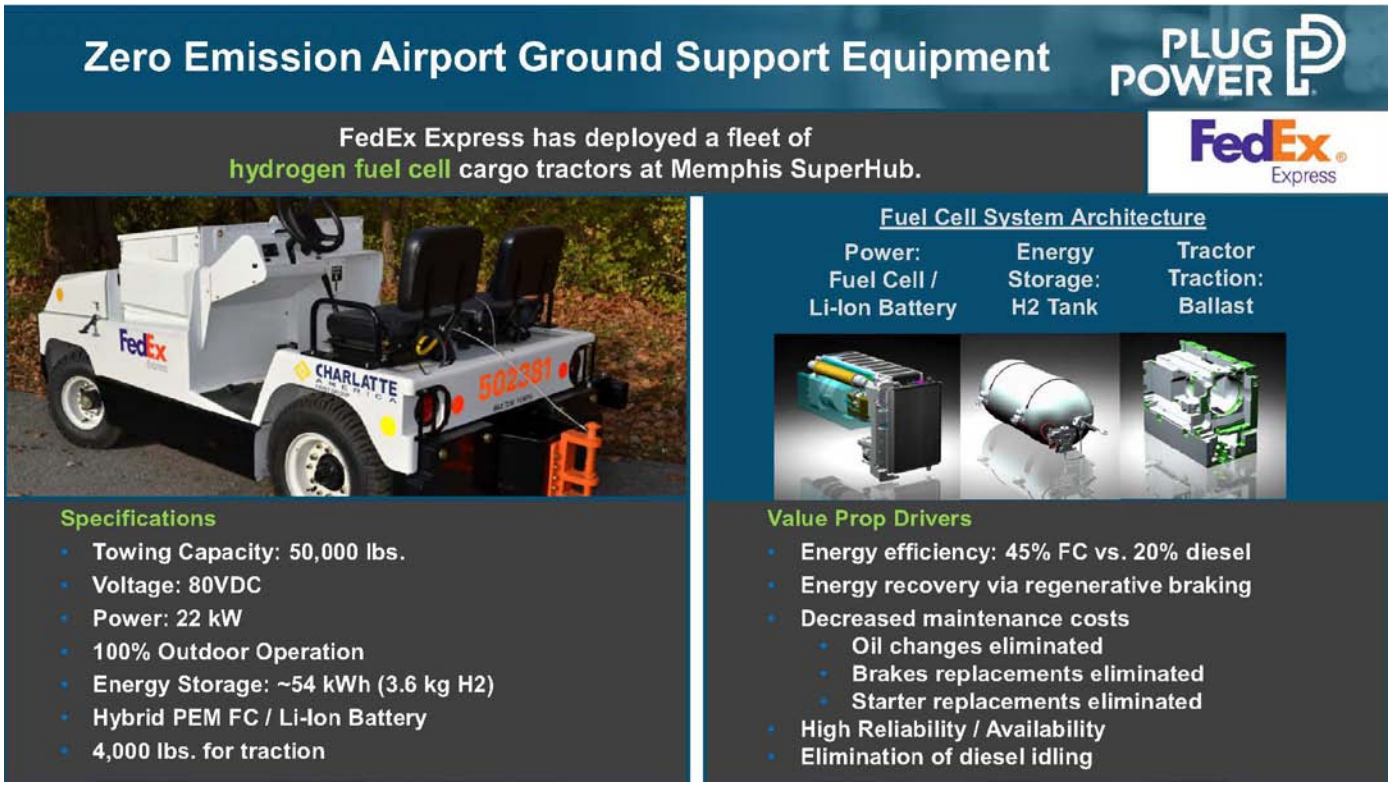

FIGURE 2. Fuel cell system as drop-in-place replacement of battery

- Site preparation – complete
- Commissioning – complete
- First year of demonstration – complete
- Assessment after Year 1 – complete
- Second year of demonstration – third quarter of 2016 to fourth quarter 2017
- Assessment after Year 2 – fourth quarter of 2017

RESULTS

The program delivered a tractor that meets the application requirements in terms of towing the required weight in an outdoor airport application even in the face of elevated hydrocarbon emissions. Stack lifetime has not been sufficient. The program has recovered with a system redesign using Plug Power stacks. The demonstration continues with

FIGURE 3. Liquid hydrogen station on airport ramp

design and service improvements in order to validate the changes made as a result of the learning in the first year.

CONCLUSION AND UPCOMING ACTIVITIES

The first year showed that fuel cells are technically viable for ground support equipment operations. The fuel cell stack is critical to demonstrate lifetime and economic viability. Upcoming activities include to continue the deployment of the redesigned fuel cell solution in the tractor fleet. Focus of the second year of demonstration is on system lifetime, reliability, and economic evaluation.

FY 2017 PUBLICATIONS/PRESENTATIONS

1. J. Petrecky, "MT011 Ground Support Equipment Demonstration," presented at the DOE Annual Merit Review, Washington, DC, June 7, 2017.