IX.4 Ground Support Equipment Demonstration

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Contract Number: DE-EE0006093

Project Start Date: January 2013
Project End Date: December 2016

Overall Objectives

- To create a hydrogen fuel cell-based solution as a cost-competitive and more energy-efficient baggage tow tractors (airport vehicle) compared to the incumbent internal combustion engine-powered vehicles.
- To enable airport end users to accomplish their daily tasks with a hydrogen fuel cell solution while reducing consumption of gasoline and diesel fuels, reducing U.S. demand for petroleum.
- To demonstrate lower carbon emissions with fuel cells.
- To demonstrate a value proposition that shows decreased energy expenditures when compared to diesel-powered airport vehicles.

The project objectives are listed in Table 1.

Fiscal Year (FY) 2014 Objectives

- Plug Power develops the 80-V fuel cell product for baggage tow tractor
- Testing with Charlatte CT5E baggage tow tractor
- Factory acceptance test to demo equivalent operation as battery/internal combustion engine tow tractors
- Plug Power conducts site planning to install hydrogen at host site
- Start of the demonstration

Technical Barriers

- Upsizing GenDrive architecture from current 48-V product to 80-V
- Outdoor application – need for weatherproofing

Technical Targets

Technical targets for this project are listed in Table 2.

FY 2014 Accomplishments

- Fuel cell testing
- Alpha prototype demonstration
- Beta prototype demonstration in Charlatte CT5E tug
- Safety planning—fuel cell/hydrogen infrastructure
- Site planning/coordination with FedEx Express for hydrogen preperation/permits
- DOE event at Plug Power demonstrating the technology
- Site planning at Memphis

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TABLE 1. Specific Project Objectives and Expectations

DOE Project Objectives	Plug Power-FedEx Project Expectations
Reduce petroleum consumption	Each BTT uses ~2 gal/hr. Total BTT run time of 15 BTT's over 2 years will be upwards of **175,200 gallons of diesel fuel reduced.**
Reduce emissions at airports	AT 9.8 kg CO2 per gal of diesel, there will be upwards of **1717 metric tonnes of CO2 eliminated at airports.**
Operate 10 hrs/day & 5,000+ hours	BTT operation occurs during two shifts: day (10AM-2 PM) and night (10PM-2AM). The total clock day is 10AM-2PM (16 hours). **Actual BTT activity is 8 hours per day. Total run time of 15 BTT's over 2 years will be upwards of 87,600 fleet hours.**
Towing capability of 3,000 to 6,000 lbs.	The BTT will be able to tow 4 FedEx containers each weighing 40,000 lbs. The corresponding **drawbar capacity of the fuel cell-powered BTT is 5,000 lbs.**
Accelerated development of FC-powered GSE	**Fleet of 15 80V fuel cell systems in real world application in 2013 gaining significant field experience while allowing a premier BTT end user to evaluate for larger deployments.**

BTT - baggage tow tractor; FC - fuel cell; GSE - ground support equipment

TABLE 2. Project Technical Targets

Comparison of BTT Specifications (Fuel Cells vs. Diesel and Battery)					
Specifications	**Units**	**Current GenDrive (48V MHE)**	**Proposed GenDrive (80V BTT)**	**Diesel[1] (Tug MA Model)**	**Battery (80V)**
Startup Time[2]	min @ 0 °C	0	0	15	0
Maximum Output Power (kW)[3]	kW	10	~20	36.5 - 64[4]	10 @ 5 hrs
Minimum Output Power (kW)[5]	kW	0	0	3.6 - 6.4	
Energy Storage Capacity @ Rated Efficiency[6]	kW-hr	26.7	37.1	147.1	29
Run Time[7]	hrs	~ 8	8-10 (full shift)	7.75	~ 4-6
Operating Temperature Range[8]	deg C	-22°–104°F	-22°–140°F	See note 8.	-4°–140°F
Durability (power degradation with time)[9]	%	10%	10%	Minimal	80%
Fuel Cell Stack and Battery Voltage Degradation[10]	%	0%	0%	-	14%
Cycle Life	cycles	NA	NA	NA	1000 - 1200
Electrical Efficiency	%	45%	45%	20%	58% from grid
Refueling / Recharging Time	minutes	2	2	5	480
Availability	%	> 95% (~98.5%)	> 95% (~98.5%)	> 80%	> 95%
Scheduled Maintenance[11]	hrs	2,000	1,000	1000	200
Estimated Mean Time Between Failure (MTBF)[12]	hrs	425	250-500	250	1000
Emissions (CO) Level @ BTT	kg CO / unit	0	0	9.8 / gallon	0

[1] Diesel Tug MA model used a representative diesel BTT. This is a very popular model in used in the BTT market.
[2] Diesel generally need to be started for 15 to 20 minutes before usage at freezing or below. (Customer engagement interviews)
[3] Maximum output for batteries is rated at 5 hours. Battery capacity assumed to be 625 A-hr.
[4] Net brake hp at governed RPM. The range represents the different engines that can be selected.
[5] No minimum turndown for GenDrive or battery. Minimum turndown for diesel engines is typically 10% of rated power.
[6] Energy Storage * Efficiency = Storage Capacity. Diesel BTT holds 15.5 gallons. Diesel has 37.95 kW-hr per gallon. Hydrogen has 33 kW-hr per kg.
[7] Run time for diesel is calculated by dividing 15.5 gallon tank by 2 gallons per hour consumption. Significant energy is consumed by idlng.
[7] The batteries and fuel cell don't need as much energy onboard because energy is only consumed when needed (little idling) and due to regenerative braking.
[8] See note 2. Diesel engine needs to warm up before usage in freezing temps. Available energy run time drops by 40-60% in freezing conditions.
[8] At very cold temps, diesel engines use resistive heaters in the intake manifold to warm the inlet air for starting or until the engine is warm.
[8] Diesel fuel is also prone to waxing or gelling in cold weather. Number 2 diesel begins to cloud at 32 deg F due to the paraffin in the fuel solidifying.
[9] By definition, battery voltage (power) degrades to 20% of the state of charge at fully charged condition.
[10] Fuel cells are able to maintain output voltage throughout the shift. Batteries will drop 14% from 100% state of charge (SOC) to 20% SOC.
[11] Scheduled maintenance for fuel cells is air filter replacement. This will increase in frequency for BTT from MHE due to additional contaminants at airport.
[11] Diesel engine maintenance include oil changes, oil filters, and air filters. Battery maintenance include equalization charges once per month at a minimum.
[12] Demonstration-level fuel cells will have roughly 10 maintenance calls per year. This is expected to decrease to 5-6 with field experience

INTRODUCTION

This project will deploy 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-V (~20 kW) fuel cell system for the BTT application. The second is a two-year demonstration where a fleet of BTTs are integrated into Charlatte CT5E electric tow tractors and deployed at the FedEx locations under real world conditions. The fuel cell fleet will be fueled by a GenFuel hydrogen compression, storage, and dispensing solution.

APPROACH

Plug Power will design an 80-V fuel cell system as a drop in place replacement of an electric Charlatte tug (see Figure 1).

Hydrogen will be supplied to the tugs via GenFuel hydrogen infrastructure, which will provide onsite hydrogen at 350 bar to be dispensed directly to the fuel cell in the tug (see Figure 2).

- Definition of Requirements – complete
- Alpha Prototype – complete
- BTT Beta Builds – Q3 2014
- BTT Testing and Certification – Q3 2014
- Site Preparation – Q2, Q3 2014

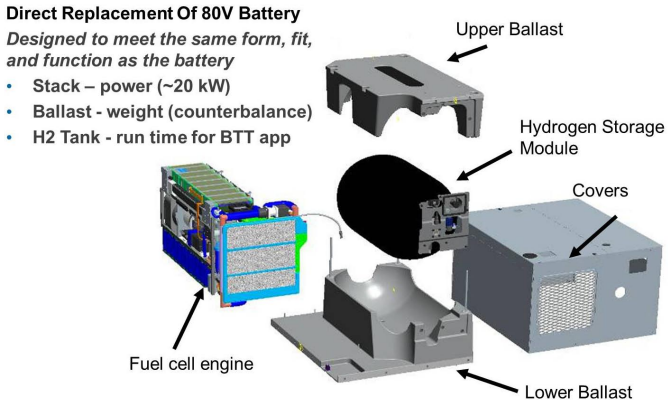

FIGURE 1. Direct Replacement of 80-V Battery

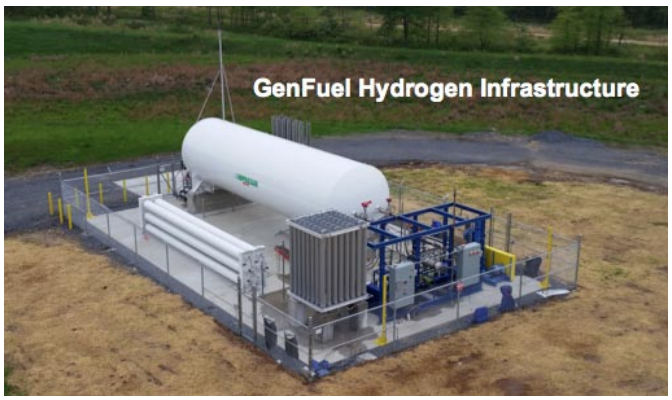

FIGURE 2. Hydrogen Solution

- Commissioning – Q4 2014
- Demonstration – Q4 2014 to Q4 2015
- Assessment after Year 1 – Q4 2015
- Demonstration – Q4 2015 to Q4 2016
- Assessment after Year 2 – Q4 2016

RESULTS

The kickoff of the project occurred on March 27, 2013. Results will be communicated in quarterly reports later this year.

CONCLUSIONS AND FUTURE DIRECTIONS

The demonstration of 15 BTT units at Memphis will begin in Q4 2014.