X.3 Direct Methanol Fuel Cell Material Handling Equipment Demonstration

Todd Ramsden
National Renewable Energy Laboratory
15013 Denver West Parkway
Golden, CO 80401
Phone: (303) 275-3704
Email: todd.ramsden@nrel.gov

DOE Manager
HQ: Peter Devlin
Phone: (202) 586-4905
Email: Peter.Devlin@ee.doe.gov

Subcontractor:
Oorja Protonics, Inc., Fremont, CA

Project Start Date: June 1, 2010
Project End Date: March 31, 2013

Fiscal Year (FY) 2012 Objectives

- Operate and maintain fuel-cell-powered material handling equipment (MHE) using direct methanol fuel cell (DMFC) technology.
- Compile operational data of DMFCs and validate their performance under real-world operating conditions.
- Provide an independent technology assessment that focuses on DMFC system performance, operation, and safety.
- Evaluate the market viability of using DMFCs in material handling applications.

Barriers

This project addresses non-technical issues that prevent full commercialization of fuel cells.

Technical Targets

No specific technical targets have been set.

FY 2012 Accomplishments

- 75 DMFC systems and their supporting methanol fueling infrastructure were operated and maintained at four customer warehouse sites for real-world use and testing in Class III MHE.
- DMFC MHE accumulated 6 to 12 months of operations per lift, totaling more than 160,000 hours of operation (as of December 2011).
- DMFC operational data for more than 6,000 methanol fueling events were collected and analyzed. Analysis determined that DMFC MHE average ~10 hours of operation between fills, allowing a full labor shift to be completed without refueling.
- Product improvements were developed and implemented, enabling better performance and reliability of DMFC systems operating in cold-temperature environments (refrigerated warehouses). Upgraded DMFC systems had 40% lower unscheduled maintenance events compared to original systems.

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Introduction

The National Renewable Energy Laboratory (NREL) and the U.S. Department of Energy (DOE) are interested in supporting the development of early market applications for fuel cell technologies. A study by Battelle Memorial Institute, "Identification and Characterization of Near-term Direct Hydrogen Proton Exchange Membrane Fuel Cell Markets," showed that fuel cells have the potential to power material handling equipment (also known generically as forklifts) at a lower overall cost than lead-acid batteries for certain types of operations [1]. Battery-powered forklifts typically use lead-acid batteries that can only provide enough power for one 8-hour shift. Multi-shift operations therefore generally require additional battery packs and battery change-outs, which reduces productivity and increases costs of operation.

NREL and DOE are currently evaluating the benefits of hydrogen-fueled polymer electrolyte membrane (PEM) fuel cells for MHE and have found that PEM fuel-cell-powered MHE can have a lower total cost of ownership compared to battery-powered forklifts [2,3]. As a supplement to the hydrogen-fueled PEM fuel-cell-powered forklift deployment testing, NREL is investigating the use of DMFC technologies in material handling applications. DMFCs, which use a liquid methanol fuel, hold promise to deliver many of the same operational benefits of hydrogen-powered fuel cell MHE, including long run times, short fueling times, and increased productivity. Liquid alcohol fuels such as methanol offer reduced infrastructure costs, high energy density, and low overall fueling costs.

Approach

NREL has partnered with Oorja Protonics on a project to demonstrate and evaluate DMFCs to provide power for material handling equipment in four commercial wholesale distribution centers. In total, 75 DMFC-powered Class III pallet jacks have been deployed in warehouses operated by Unified Grocers, Testa Produce, and Earp Distribution. DMFC lifts are being operated two shifts per day for a 15-month deployment, with 3,500 to 5,000 total operational hours expected on each unit.

As part of the project, Oorja built, tested, and deployed its OorjaPac Model 3 DMFC power pack into Class III pallet jacks. The DMFC system delivers an output power of approximately 1.5 kW and includes a 3-gallon methanol storage tank expected to provide approximately 12 hours of autonomy between fuelings. Methanol fuel is being dispensed to the DMFC MHE using the OorjaRig methanol dispenser, which is designed to meet all relevant fire and safety codes for indoor methanol dispensing. Oorja is collecting data on both the DMFC systems and the supporting methanol fueling infrastructure. NREL is compiling and analyzing these data and is providing a third-party assessment on the performance of DMFCs used in material handling applications.

Results

During the first six months of 2011, 75 DMFC systems and their supporting methanol fueling infrastructure were deployed at end-user warehouse sites for real-world use and testing in Class III MHE. The DMFC MHE fleets continue to be operated and maintained, and detailed system-level data have been collected by Oorja and provided to NREL for analysis. The data include dozens of system parameters captured 10 times per minute, characterizing a wide variety of DMFC performance metrics. Detailed data analysis is performed every six months, with the latest evaluation completed in March 2012.

In total, the combined DMFC MHE fleet had more than 160,000 hours of operation as of December 2011. DMFC systems had significant usage, with over half of the units logging more than 1,500 hours of operation, and nearly 25% of the systems reaching more than 2,170 hours (see Figure 1). Overall, the three fleets operated by Unified Grocers, Testa Produce, and Earp Distribution had fleet averages of 750 hours, 1,500 hours, and 1,800 hours per DMFC system.

The OorjaPac Model 3 DMFC power packs used in this deployment project act in concert with traditional MHE battery systems. Unlike traditional battery systems that have limited run time and require frequent battery changes and charging from the electricity grid, the OorjaPac DMFC system acts as an onboard battery charger, maintaining the battery pack state-of-charge and eliminating electric-grid-based battery charging. Under this configuration, actual DMFC operation time depends on the battery state-of-charge. With a high charge level, the DMFC system may turn off while the pallet jack continues to be used. Hence, the operation hours noted above reflect actual run-time of the DMFC systems but may underestimate actual MHE hours of operation.

The DMFC Class III pallet jacks are deployed in warehouses operating two shifts per day. Data provided indicate that DMFC systems are typically operated 7 to 12 hours per day (with actual MHE operation hours potentially

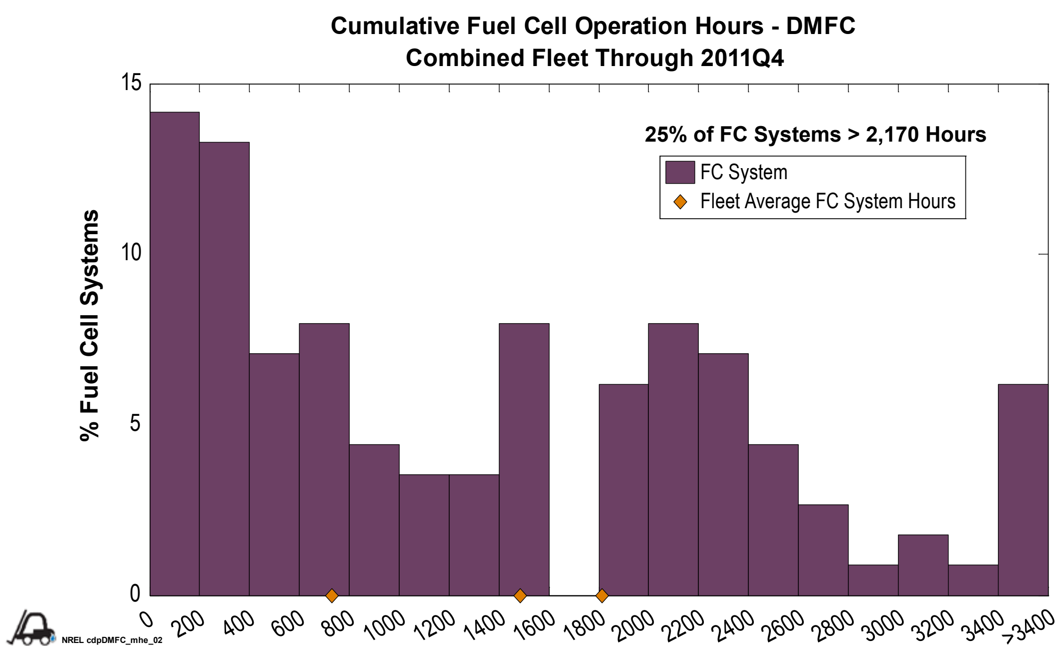

FIGURE 1. Operation Hours for DMFC Systems

higher). Based on an analysis of more than 6,000 methanol fueling events, NREL found that DMFC systems operate for an average of 9.8 hours between methanol fuelings (see Figure 2). Thus, the DMFC systems can easily operate for a full shift on a single methanol fill, and given their typical use pattern, they can often operate for a complete two-shift day on a single fill. Reflecting this, analysis of the methanol fueling data shows that the DMFC systems are filled one time per day on average.

This demonstration project provided the opportunity to deploy DMFC MHE in cold-temperature, refrigerated environments. Initial DMFC system designs were not optimized for cold-temperature operation, leading to a variety of unscheduled maintenance events and, in some cases, early DMFC stack failures. Oorja conducted a fault analysis of systems exhibiting problems and found common failure modes. Based on their analysis, Oorja developed system and technology improvements to DMFC methanol concentration control, electronics control, and fuel fittings, and incorporated those into the DMFC fleet. An analysis of unscheduled maintenance events before system upgrades and after fleet-wide electronics control and fuel fitting upgrades (and an initial rollout of upgrades to methanol concentration control) showed that unscheduled maintenance events were reduced by 40% (see Figure 3).

NREL analyzed individual DMFC systems to characterize system voltage, current, and power; maximum voltage and power over time; and stack voltage decay. DMFC systems typically operate at high current and power levels (with power generally above 1 kW) and within a tight voltage range of 30–36 volts (see Figure 4). The DMFC systems that exhibited problems and early stack failures prior to the rollout of system upgrades and technology improvements operated below 30 volts and across a wide range of power levels, and showed more significant overall stack voltage degradation.

Detailed analysis of the upgraded DMFC fleet following technology improvements will continue, but initial analyses indicate significant performance improvement in the upgraded fleet. The DMFC fleet also has demonstrated long run-times and autonomy between methanol fuelings, enabling increased productivity by avoiding the need for multiple and time-consuming battery changes during the workday. In FY 2013, a total cost of ownership analysis will be conducted for DMFC MHE that will incorporate data analyses of system performance, maintenance, and methanol fueling.

Conclusions and Future Direction

- 75 OorjaPac DMFC systems and their associated methanol fueling infrastructure were operated and maintained at customer warehouse sites for real-world use and testing.

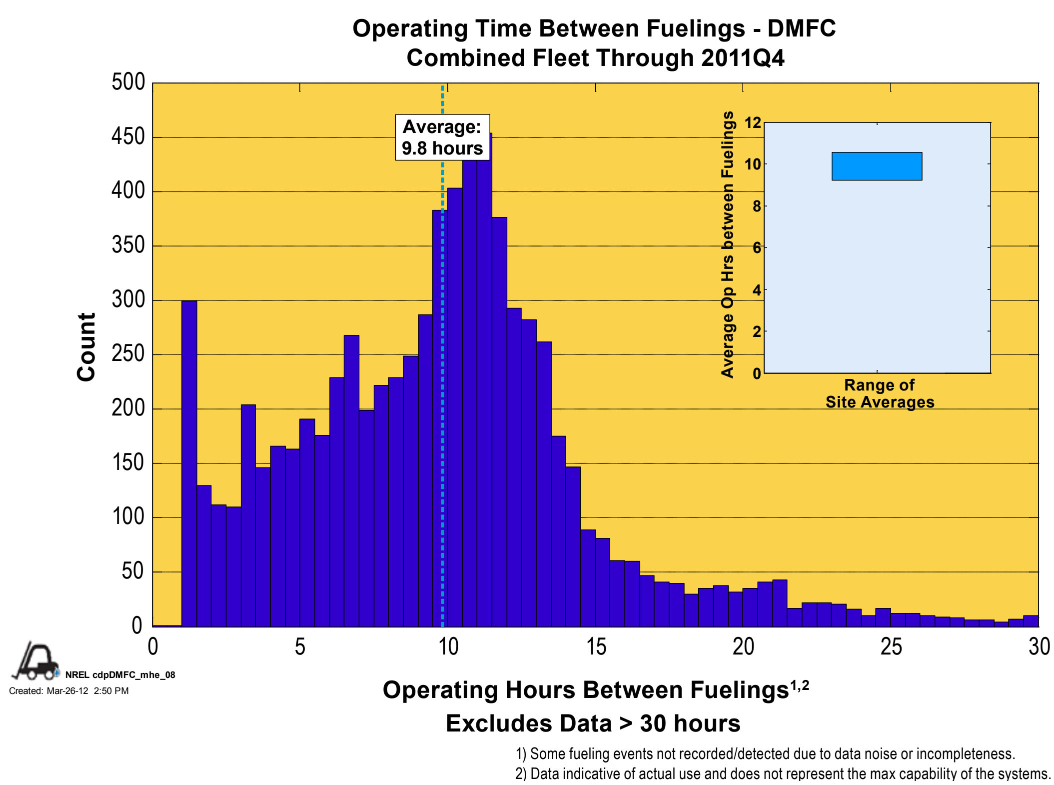

FIGURE 2. DMFC Operation Hours between Fuelings

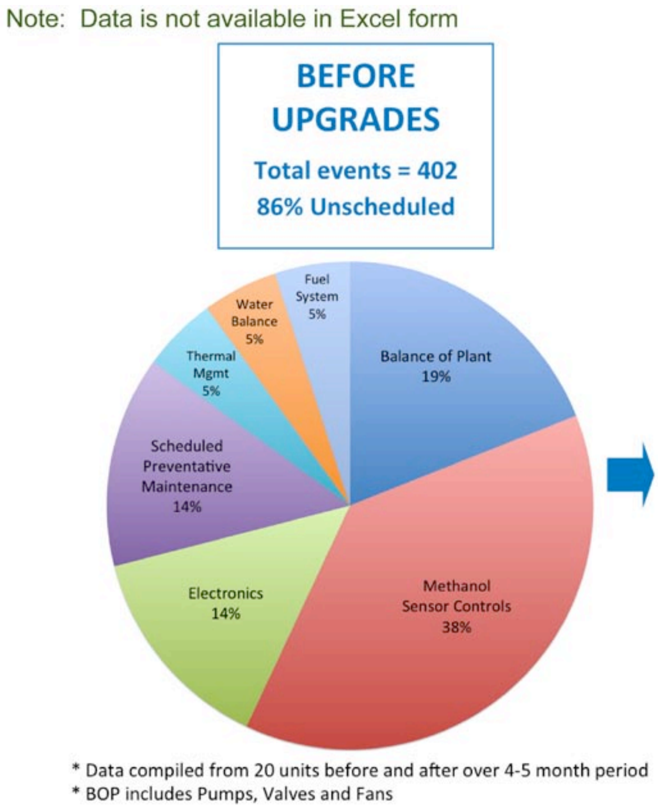

FIGURE 3. Maintenance Events Before and After DMFC System Changes

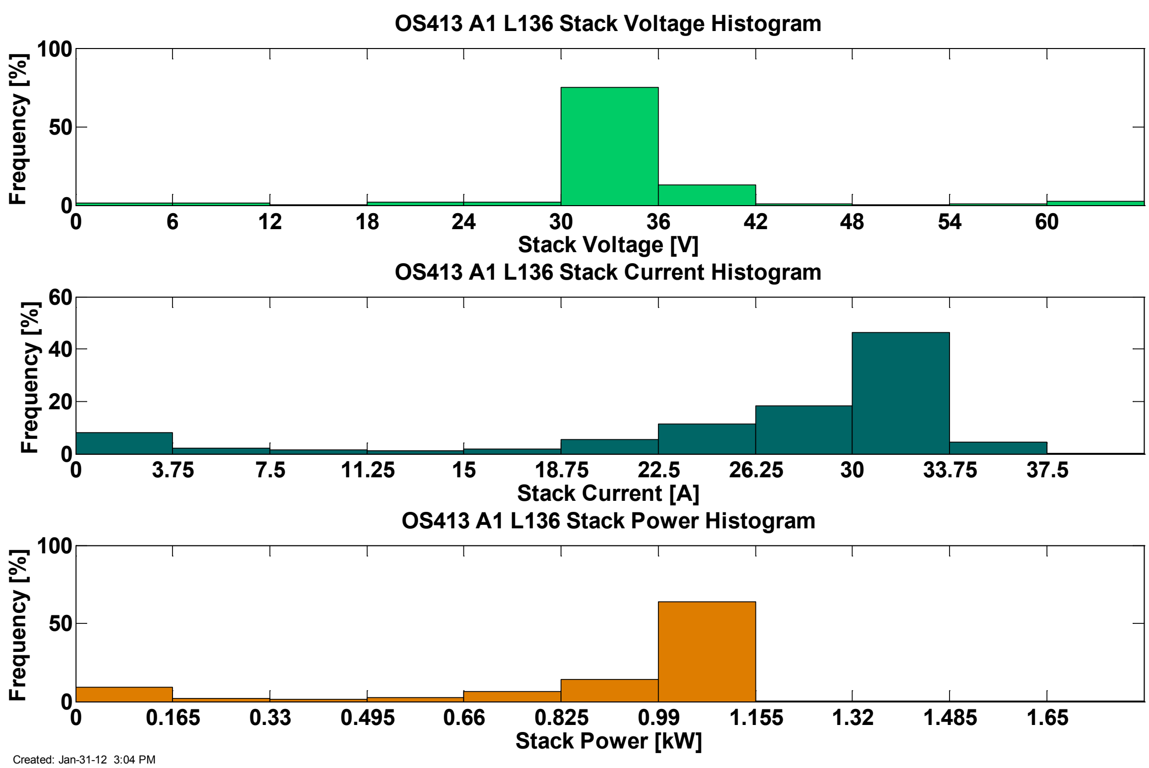

FIGURE 4. Typical DMFC Voltage, Current, and Power Levels during Use

- DMFC systems in the demonstration operate an average of 9.2 hours per day. These DMFCs average 9.8 hours of operation between fueling, and the systems average one fueling per day.
- Initial DMFC system designs showed reliability issues, particularly related to operation in cold-temperature environments. Initial analyses of the maintenance and performance of upgraded DMFC systems show significant improvement.

In the next year, NREL will use real-world operating data to characterize the performance of DMFC systems used in material handing applications, including evaluation of:

- Performance, reliability, and maintenance of deployed DMFC systems, particularly the performance of DMFC systems incorporating the latest technology improvements.
- Business case analysis of DMFC systems compared to typical battery-only systems for Class III MHE, including an assessment of equipment costs, maintenance costs, productivity and labor costs, and costs of fuel and fueling infrastructure.

FY 2012 Publications/Presentations

1. Todd Ramsden, “Direct Methanol Fuel Cell Material Handling Equipment Deployment,” DOE Hydrogen and Fuel Cells Program Annual Merit Review, May 16, 2012, Washington, D.C.

References

1. K. Mahadevan et al., “Identification and Characterization of Near-Term Direct Hydrogen Proton Exchange Membrane Fuel Cell Markets,” Battelle. April 2007.

2. National Renewable Energy Laboratory, “Hydrogen and Fuel Cells Research: Early Fuel Cell Market Demonstrations.” http://www.nrel.gov/hydrogen/proj_fc_market_demo.html.

3. National Renewable Energy Laboratory, Hydrogen Technologies and Systems Center’s Technology Validation Program, “Total Cost of Ownership for Class I, II, & III Forklifts,” March 2012. http://www.nrel.gov/hydrogen/cfm/images/cdp_mhe_58_totalcostofownership.jpg.