X.3 Maritime Fuel Cell Generator Project

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Project Start Date: September 15, 2013
Project End Date: Project continuation and direction determined annually by DOE

Overall Objectives

- Lower the technology risk of future port fuel cell deployments by providing performance data of hydrogen proton exchange membrane (PEM) fuel cell technology in the marine environment.
- Lower the investment risk by providing a validated business case assessment for this and future potential projects.
- Enable easier permitting and acceptance of hydrogen fuel cell technology in maritime applications by assisting U.S. Coast Guard and the American Bureau of Shipping develop hydrogen and fuel cell codes and standards.
- Act as a stepping stone for more widespread shipboard fuel cell auxiliary power unit deployments.
- Reduce port emissions with this and future deployments.

Fiscal Year (FY) 2016 Objectives

- Enable new maritime-specific regulations for hydrogen and fuel cells.
- Enable new user experiences.
- Lower technology and business risk.
- Maintain hydrogen infrastructure capability on Oahu in support of this and future strategic projects.

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.

(A) Inadequate standards and complex and expensive permitting procedures

(E) A lack of flexible, simple, and proven financing mechanisms

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

Technical Targets

No specific technical targets have been set.

FY 2016 Accomplishments

- Performed on-site commissioning of the generator at Young Brothers (YB) and completed operational turnover to YB personnel.
- Performed eight refuelings for a total of ~400 kg of dispensed hydrogen at the Hickam Air Force Base station.
- Ran for 55 d and ~250 h, displacing 6,660 kWh of diesel generator fuel and emissions, powering 130 refrigerated containers.
- Concluded the YB deployment.

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INTRODUCTION

Fuel costs and emissions in maritime ports are an opportunity for transportation energy efficiency and emissions reduction efforts. For example, a 2004 study showed the Port of Los Angeles had average daily emissions exceeding that of 500,000 vehicles [1]. Diesel fuel costs continue to rise as low-sulfur limits are imposed, making power generation more expensive for fleets. Hydrogen fuel cells have the potential to meet the electrical demands of vessels in the port as well as supply power for other port uses such as yard trucks, forklifts and other material handling specialty equipment. Validation of the commercial value proposition of both the application and the hydrogen supply infrastructure is the next step towards widespread use of hydrogen fuel cells in the maritime environment, and is determined by meeting necessary equipment and operating costs and customer expectations such as reliability, form, and function.

Sandia National Laboratories' recent report, "Vessel Cold-Ironing Using a Barge Mounted PEM Fuel Cell: Project Scoping and Feasibility," identified several opportunities for demonstrating technical and commercial viability of a fuel cell in the maritime environment [2]. One identified opportunity is in Honolulu Harbor at the Young Brothers Ltd. wharf. YB provides barge transport of goods between Oahu and the Hawaiian neighbor islands and is an ideal demonstration location because of their high fuel costs and corporate interest in low emission, low environmental impact solutions. YB uses refrigerated containers ("reefers"), which keep perishable goods cold while on the dock and on the barge by using dedicated diesel generators mounted inside mobile 20-ft containers. Sandia's report concluded that it is technically feasible to build a containerized hydrogen fuel cell generator to replace the diesel generator in YB operations.

APPROACH

This project developed and demonstrated a nominally 100 kW, integrated fuel cell prototype for marine applications. This project brought together industry partners in this prototype development as a first step towards eventual commercialization of the technology. To be successful, the project incorporated interested industry and regulatory stakeholders: an end user, technology supplier and product integrator, and land- and maritime-based safety and code authorities. Project costs were shared by the primary stakeholders in the form of funds, in-kind contribution, and material/equipment either loaned or donated to the project. Funding provided by the Department of Transportation Maritime Administration (MARAD) was used to provide assistance with the integrated system and packaging designs, data collection and assistance during the demonstration period, and technical assistance and project management throughout the project. In addition some MARAD funds were used to purchase specialized equipment needed to construct the prototype. DOE funds were used to provide overall project management, technical design assistance, and deployment facilitation, and used via subcontract to the prototype manufacturer for the design, build, and testing of the final product.

The project had four phases:

1. Establishment and specification (September 2013–December 2013)
2. Detailed design and engineering (January 2014–March 2015)
3. Prototype fabrication and site construction (October 2014–June 2015)
4. Deployment (onsite demonstration at YB) and analysis (August 2015–September 2016)

RESULTS

The generator was commissioned on-site in the fourth quarter of FY 2015 over 12 d and placed into service in the YB fleet (Figure 1). Commissioning included first fill at the Hickam station, which was performed with no issues. During this period 20–30 YB staff were given hands-on training and experience with the generator (Figure 2).

FIGURE 1. The Maritime Fuel Cell Generator (blue container, middle left) contains 75 kg of compressed hydrogen storage and produces over 100 kW net electricity, packaged in a 20-ft shipping container. Here it powers refrigerated containers at Young Brothers, Ltd. in Honolulu Harbor.

FIGURE 2. Nader Zaag (left) from Hydrogenics provides hands-on training to Young Brothers operators. Over 100 YB personnel were given hydrogen familiarity and/or operational training through this project.

Following that, a "ribbon-cutting" ceremony organized by Sandia and hosted by YB welcomed 55 people, mainly in the energy industry, military/government sectors, and project partners (Figure 3). It included speeches by Senator Brian Schatz (Hawaii), Mark Glick (Administrator, Hawaii State Energy Office), Pete Devlin (DOE–Office of Energy Efficiency and Renewable Energy–Fuel Cell Technology Office), John Quinn (Associate Administrator for Environment and Compliance, MARAD), Ryan Sookhoo (Director of New Initiatives, Hydrogenics), Glenn Hong, (President of Young Brothers) and Marianne Walck (Vice President of Energy and Climate, Sandia).

Concurrent with the ribbon cutting the project's outreach team issued a press release announcing the event and the start of the on-site deployment. An accompanying video described the technology and the project's objectives. The press release was reprinted in 36 unique locations on the web with approximately 10.5 million page views since its issuance.

Throughout the subsequent deployment usage data was compiled and tracked by Sandia. This included detailed and summary technical information whenever the generator is used, maintenance logs, and refuelings. This was done in a format compatible with the existing data collection activities at the National Renewable Energy Laboratory for other projects (primarily material handling equipment). The Sandia team has devised a method for determining the actual mass of hydrogen dispensed into the unit during fills from Hickam despite the fact there are no flow measuring devices at that station that are active when fueling the generator. The Sandia team has also been working to calculate fuel burn rates for different usage scenarios, which is desired by the YB operators, and gross and net efficiency curves, made difficult because of no direct measurements of net power.

The overall generator usage during the deployment fell short of expectations. Both technical and administrative/personnel factors were the reasons for the low usage. Technical issues were primarily due to the inverter, which had nine issues over the course of the deployment resulting in over 90 cumulative days of downtime. Inverter issues ranged from controls/software to isolated circuit board failures. Battery issues were second in frequency and resulting downtime, with seven issues and more than 60 days resulting downtime. Battery issues were primarily an inability to provide sufficient voltage to start the system, sometime compounded due to long times between runs and battery depletion during off periods. The battery was replaced in third quarter of FY 2016. Detailed descriptions of these and other technical issues affecting downtime will be detailed in the project's final report.

The most common administrative/personnel factor related to labor and manpower availability. Staff obligations to daily operational tasks resulted in additional days of downtime. For a perfectly operating generator the availability of personnel would be a minor issue. However, at this first generation deployment stage, technical issues with the generator required additional attention and the lack of availability of hands-on support for troubleshooting and maintenance compounded downtime. YB operators have recommended that a dedicated operator be assigned to the generator on subsequent deployments to deal with unexpected issues that commonly arise with new technology. An additional administrative factor was establishment of a

FIGURE 3. Project team members with the generator at the ribbon cutting outreach event.

formal agreement between Sandia and YB. This caused an operational delay of 35 days while both parties worked to reach mutually agreeable liability terms.

Fueling at Hickam Air Force Base was always smooth and uneventful. The generator was filled eight times over the course of the deployment, taking an average of ~60 kg each time, filling to 350 bar, and lasting an average of 27 min per fill (over 2 kg/min). The Hickam station is managed by Hawaii Center for Advanced Transportation Technologies and operated under a contract to U.S. Hybrid (Figure 4). Data exchange between the project team members helps all parties to understand the unique aspects of quickly fueling large quantities at one time and will help to enable fueling of other equipment and large vehicles in the future.

Overall, the generator ran for 55 d and ~250 h in YB custody, displacing 6,660 kWh of diesel generator fuel and emissions, and powered 130 refrigerated containers. Technical and business case analyses will be presented in the project's final report.

FIGURE 4. The generator was fueled at the Hickam Hydrogen Station (managed by Hawaii Center for Advanced Transportation Technologies and operated by U.S. Hybrid). Here is it being refueled to 350 bar with 49 kg of hydrogen in 18 min.

CONCLUSIONS AND FUTURE DIRECTIONS

The Maritime Fuel Cell Project is a wholly collaborative effort with early and continuous stakeholders feedback that facilitated removal of nontechnical barriers to hydrogen and fuel cell use.

The DOE/MARAD/Sandia project leads are currently working to arrange a follow-on deployment at a different partner following upgrade/refurbishment of generator features by the manufacturer. It is expected that this generator will continue to be deployed by various partners in the future, displacing additional diesel generator emissions and breaking down market barriers to widespread hydrogen fuel cell technology deployment at each stop.

SPECIAL RECOGNITIONS & AWARDS

1. DOE Hydrogen and Fuel Cells Program R&D Award, "For outstanding dedication to the advancement of hydrogen and fuel cell technologies in the early market, including the world's first pier-side maritime fuel cell power system," awarded to Joseph Pratt, June 2016.

FY 2016 PUBLICATIONS/PRESENTATIONS

1. Pratt, J., "Deployment of a Mobile Hydrogen Fuel Cell Generator for Ports and on Marine Vessels," Fuel Cell Seminar, November 17, 2015, SAND2016-1192 C.

2. Pratt, J., "Zero Emission Fuel Cell Power and Propulsion for Marine Applications," Ship Operations Cooperative Program, April 7, 2016, SAND2016-2848 PE.

3. Pratt, J., "Maritime Fuel Cell Generator Project," DOE Annual Merit Review, June 9, 2016, SAND2016-3746 PE.

REFERENCES

1. D. Bailey, T. Plenys, G. M. Solomon, T.R. Campbell, G.R. Feuer, J. Masters, and B. Tonkonogy, "Harboring Pollution - Strategies to Clean Up U.S. Ports," National Resources Defense Council, NY, August, 2004.

2. J.W. Pratt and A.P. Harris, "Vessel Cold Ironing Using a Barge Mounted PEM Fuel Cell: Project Scoping and Feasibility," Sandia National Laboratories, Report SAND2013-0501, available at http://energy.gov/eere/fuelcells/downloads/vessel-cold-ironing-using-barge-mounted-pem-fuel-cell-project-scoping-and.