Maritime Fuel Cell Generator Project

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We have built and deployed a containerized hydrogen fuel cell generator for reefer power on land and sea.

Project Concept

Fuel cell unit replaces diesel generators, reducing fuel cost and emissions.

Project Scope (2013-present)

Design, build, and deploy a containerized fuel cell system to supply portable power for refrigerated containers (“reefers”).

- **100 kW (net) fuel cell and H_2 storage inside a 20-foot container, ~ 4kW B.O.P.**
- **Strategic set of project partners, encompassing both the H_2-fuel cell and maritime communities.**
- **Initial deployment with Young Bros. HI.**
- **Upgraded the MarFC to 480VAC operation for general marine service.**
- **Deploy with the Scripps Institution of Oceanography for shore power.**

Project Overview

Timeline:

- Start: July 2016
- End: January 2021
- 85% complete

Budget:

- Total: $1.342 M
  - DOE FY16: $258K
  - DOE FY17: $279K
  - DOE FY19: $150K
  - DOE FY20: $50K
  - DOT/MARAD* FY17: $211K
  - DOT/MARAD* FY18: $329K
  - DOT/MARAD* FY19: $0K
  - DOT/MARAD* FY20: $65K

MT Barriers Addressed:

- A: Inadequate standards
- E: Financing mechanisms (Lack of cost and performance data)
- F: Inadequate user experience

Partners:

- Sandia *(project manager)*
- Scripps Institution of Oceanography (SIO)
- Hydrogenics *(sub w/ cost share)*

*DOT/MARAD: US Department of Transportation, Maritime Administration

Relevance – Overall Project Objectives

- ✓ **Lower the technology risk** of future port fuel cell deployments by providing performance data of H_2-PEMFC technology in this environment. (*Barrier: E*)
- ✓ **Lower the investment risk** by providing a validated economic assessment for this and future potential projects. (*Barrier: E*)

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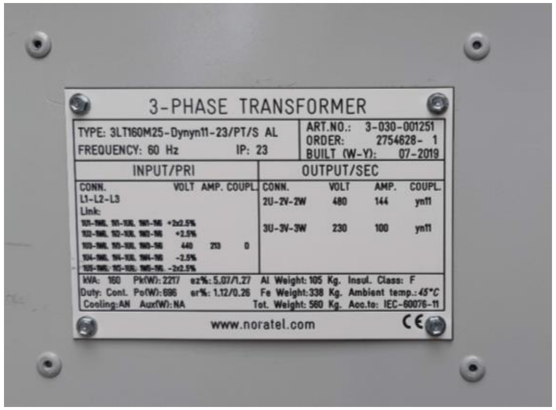
- ✓ **Enable easier permitting and acceptance** of H_2-FC technology in maritime applications by assisting USCG and ABS develop H_2+FC codes and standards. (*Barrier: A*)
- ✓ **Engage potential adopters/end users** of hydrogen fuel cells to enable more widespread acceptance of the technology. (*Barrier: F*)

Approach: July 2019 - Present

- Complete upgrade of the MarFC generator for 480 VAC operation.
- Perform 2-week test of upgrades for long-term stability and on/off cycling.
- Ship the unit from Mississauga Canada to SIO in San Diego CA.
- Inspect unit after arrival for possible damage in shipping (repair as needed).
- Engage H_2 Gas Suppliers to secure fueling contract for the MarFC.
- Introduce/train SIO staff to the MarFC hydrogen fuel-cell technology.
- Provide power to the *R/V Robert Gordon Sproul*, assess operation.
- Deploy with SIO for 6 months, providing zero-emission shore power.
- Write Final Project Report

Accomplishments and Progress: Completed MarFC Upgrade to 480VAC Operation

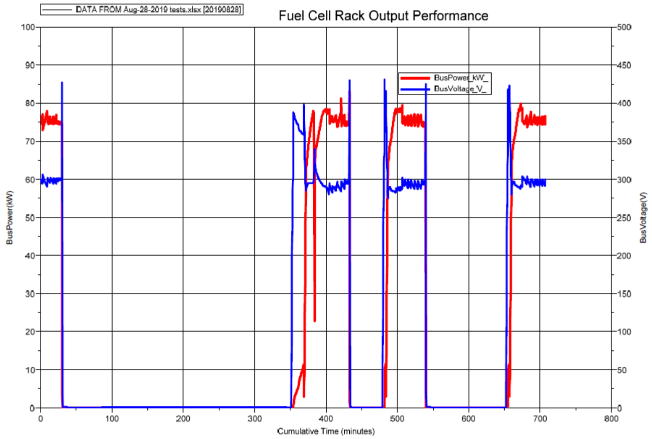
New 480VAC transformer installed



Nameplate of new transformer.

New recessed connector panel/box mounted on the MarFC unit to SIO specifications.

Accomplishments and Progress: Tested Upgrades to MarFC Unit Over 2 Weeks



MarFC testing after upgrade

Unit tested for:

- ✓ 480 VAC 3-phase operation,
- ✓ Voltage stability, check for spikes,
- ✓ Starting and stopping.
- ✓ Endurance for 10 hours,
- ✓ Variable loads.

After testing, the unit was loaded onto a truck for shipment to San Diego.

Accomplishments and Progress: MarFC Arrives at SIO with Damage, Repair Unit On-site

The unit arrived at SIO on 11/11/19 with broken PVC piping on the fuel-cell coolant recirculation system. On 12/1/19 the old glycol coolant fluid was drained, the broken piping was removed, new piping installed and new glycol fluid added.

Dave Haywood (Hydrogenics/Cummins) drains old coolant from the MarFC system.

Max Muller (Hydrogenics/Cummins) removes broken PVC piping

New Gray PVC coolant pipe successfully installed

Accomplishments and Progress: Completed First Mobile H_2 Refueling of the MarFC

First on-site MarFC refueling via H_2 delivery on 12/2/19 by IGX.

IGX H_2 refueling truck arrives at SIO

Cascade fill from IGX 350 bar truck tanks

Successful H_2 connection, grounding truck to unit.

Monitoring MarFC tank temperature during fill.

Refueling the MarFC via cascade fill from IGX H_2 delivery truck was straightforward

Accomplishments and Progress: Completed SIO Education/Training 12/3/2019

SIO staff learn about the layout, use and refueling of the MarFC both in the classroom and on the Pier.

Scripps personnel

On the Physical and Combustion Properties of Hydrogen Compared to Natural Gas

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San Diego, CA
December 3, 2019

Lennie Klebanoff describes the properties of H_2 to SIO staff

Max Muller describes the MarFC layout

Craig Van Pelt (IGX) describes the H_2 refueling procedures

Max Muller gives a tour of the MarFC H_2 storage

...and then of the fuel cell rack and power electronics

Accomplishments and Progress: First Fuel-Cell Powering of a Vessel: 12/19/2019

The first vessel powering by fuel-cell shore power–the *R/V Robert Gordon Sproul. Mechanical Systems.*


Connecting vessel cable to MarFC.


Powering deck crane.

Powering fire pump systems


Powering Deck Pump.

Sequentially brought Sproul power systems online with the MarFC. The cumulative power after each step was:

-- Lights, AC ,1 ventilation fan: ~ 22 kW

-- Hydraulics, 2nd ventilation fan: ~ 36 kW

-- Fire, steering pumps: ~ 50 kW

-- Crane operation: ~ 65 kW

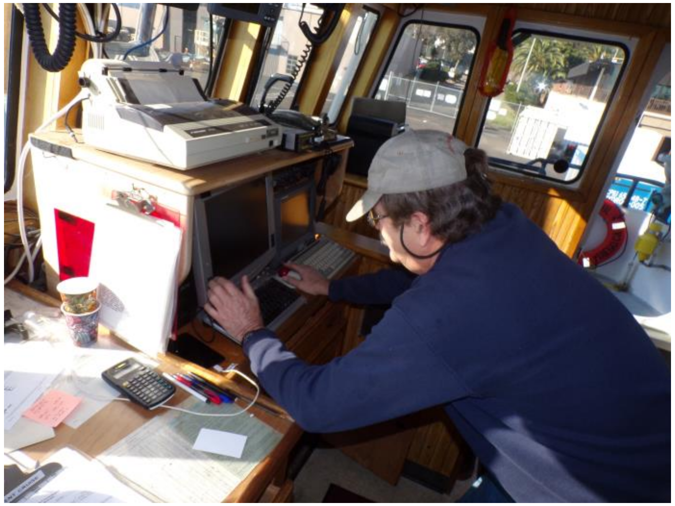
Largest transient spike in total power seen was ~ 83 kW.

All mechanical system power loads handled by the MarFC.

Accomplishments and Progress: First Fuel-Cell Powering of a Vessel: 12/19/2019

Checking the more sensitive *Computer and Science Systems.*

Capt. Chris Welton checking the Sproul uninterruptable power supply (UPS) systems in the science bay.



…and the Sproul computer systems and backup UPS systems under MarFC power.

Attempted MarFC powering of the Sproul Computer and Science Systems was not successful as the vessel UPS systems turned on and drained their batteries. Other UPS systems cycled on and off. These issues were traced to a MarFC-vessel interface grounding issue, with no damage to the vessel power systems.

The fix to the problem has been designed, and will be tested when operations begin again after the California Shelter in Place order has lifted.

Summary

- Upgraded the MarFC unit to 480 VAC operation.
- Tested the upgrades over 2 weeks for proper operation.
- Shipped the MarFC to the SIO in San Diego, CA.
- Secured H_2 fueling contract with IGX.
- Inspected the MarFC, repaired damage sustained in transit.
- Provided education/training to SIO staff on the H_2/MarFC technology.
- Conducted first H_2 fueling of the MarFC by H_2 delivery truck.
- Conducted first powering of the *R/V Robert Gordon Sproul*.

Proposed Future Work

- Implement the unit repair that resolves the MarFC-vessel interface grounding issue.
- Demonstrate via pierside test that the MarFC functions as expected.
- Attempt another powering of the *R/V Robert Gordon Sproul*, monitoring mechanical, computer and science systems.
- Conduct 6-month demonstration using the MarFC to provide shore power to the Sproul.
- Collect and analyze data from 6-month deployment.
- Write Final Report.

Photo Credit: Bruce Appelgate, SIO

Any proposed future work is subject to change based on funding levels

Collaboration and Coordination

Thanks to our partners and colleagues:

- Scripps Institution of Oceanography: Bruce Appelgate, Zoltan Kelety
- Hydrogenics/Cummins: Ryan Sookhoo, Nader Zaag, Luis Orosco, Max Muller, Dave Haywood.
- IGX: Craig Van Pelt, DeLisa Leighton, Michael Koonce.
- Sandia National Laboratories: Madelynne Farber, Jon Zimmerman

Thank You!

Photo by author

Publications and Presentations

- No publications were produced from the work.
- “Development of a Containerized 100 kW Fuel Cell System for Maritime Applications,” Lennie Klebanoff presentation to H2@Ports DOE Workshop, San Francisco, CA September 11, 2019.
- “Maritime Fuel Cell Generator Project,” DOE H_2 Program Annual Merit Review, Washington D.C., May 31, 2020.

Critical Assumptions and Issues

1. We need to find a deployment site that does not require indemnification.

   SIO satisfies this requirement.

2. Cost of delivered hydrogen is still currently high (> $50/kg), which is a burden on the deployment site.

   We are working with the H_2 suppliers to provide hydrogen within the existing project funding.