VII.4 Hydrogen Component Validation

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Project Start Date: October 1, 2011
Project End Date: Project continuation and direction determined annually by DOE

Overall Objectives

- Collaborate with industry to test and validate the commercial readiness of hydrogen systems components and systems.
- Develop and work with industry to provide advanced functionality and innovative solutions of near-commercial hydrogen systems.
- Working with DOE and other key stakeholders, by 2020, validate large-scale systems for grid energy storage that integrate renewable hydrogen generation and storage with fuel cell power generation by operating for more than 10,000 hours with a round-trip efficiency of 40%.

Fiscal Year (FY) 2013 Objectives

- Install, perform accelerated testing on, and analyze performance of hydrogen compressors.
- Establish cooperative research agreements with industry partners to enable equipment loans and testing of advanced systems at NREL.
- Monitor system faults and downtime of the Hydrogen Component Validation Project system and report composite data products alongside comparable sites.

Technical Barriers

This project addresses the following technical barriers from the Technology Validation section of the Fuel Cell Technologies Office 2012 Multi-Year Research, Development, and Demonstration Plan:

(D) Lack of Hydrogen Refueling Infrastructure Performance and Availability Data

(G) Hydrogen from Renewable Resources

Technical Targets

This project is focused on testing and validation efforts to better integrate hydrogen systems and measure their ability to deliver low-cost hydrogen from production through dispensing. However, the project is flexible and has been retargeted in FY 2013 to focus on performing accelerated life testing of both diaphragm and piston hydrogen compressors. Projects in the Technology Validation sub-program are both “learning demonstrations” to help guide and manage the hydrogen and fuel cell component and materials research and development activities, and a validation of the technology under real-world operating conditions against durability and performance targets. While compressor performance metrics are being developed and integrated with this Technology Validation work plan, hydrogen compression can be found included in Task 3 of the Technology Validation section of the Fuel Cell Technologies Office Multi-Year Research, Development, and Demonstration Plan.

Task 3 – Hydrogen Delivery, Production, and Refueling

- Milestone 3.3: Validate large scale (>100 kg/day) integrated wind-to-hydrogen production system. (2Q, 2015)
- Milestone 3.9: Validate large-scale system for grid energy storage that integrates renewable hydrogen generation and storage with fuel cell power generation by operating for more than 10,000 hours with a round-trip efficiency of 40%. (4Q, 2020)

FY 2013 Accomplishments

- Installed and began accelerated life testing of pneumatically-driven piston hydrogen gas booster.
- Established a Cooperative Research and Development Agreement (CRADA) with PDC Machines. Started process for a second CRADA with Proton Onsite.
- Reported detailed reliability metrics for the Xcel Energy/NREL demonstration project relative to other hydrogen stations operating at 350 bar.

INTRODUCTION

The Hydrogen Component Validation project is advancing the integration of renewable electricity sources with state-of-the-art hydrogen production, compression, storage, and dispensing systems. The project work scope includes quantifying the operation and maintenance, durability, and reliability under near-real-world operating conditions to support DOE validation of these metrics. Insights gained from this work benefit the hydrogen-based industry and relevant stakeholders as the market for this equipment and products expands. Progress in on-site production, compression, and storage at fueling stations will continue to be validated as the technology improves and is scaled up.

Today, one of the project's primary goals is to validate the performance and reliability of hydrogen production (via renewable electrolysis) and compression systems as they are applied to hydrogen as an energy storage medium and for vehicle refueling. The project includes optimization of the electrical pathway (i.e., power conversion) between renewable sources and the electrolyzer and compression systems of hydrogen at various pressures.

APPROACH

This project provides a flexible, independent testing platform and verification of the technical readiness of advanced integrated systems by operating them from the grid and renewable electricity sources. Real-world data from daily system operation are revealing opportunities for improved system design, optimization, and unique hardware configurations to advance the commercialization of these technologies. Lessons learned and data-driven results provide feedback to DOE, industry, and the analytical and modeling components of other sub-programs.

RESULTS

In FY 2013, NREL, using various funding mechanisms (e.g., work for others, internal, and CRADA), expanded the capabilities of the Hydrogen Component Validation project. The system was designed as a flexible platform enabling quick installation, testing, and reporting of critical equipment performance for DOE and industry.

In FY 2013, NREL established a CRADA with PDC Machines, a leading manufacturer of diaphragm compressors. This CRADA is focused on a fully instrumented 700-bar compressor and performing highly accelerated life testing at NREL. The system is expected to be fully integrated with NREL's system, including data acquisition to improve reporting of test results and to feed back lessons learned to PDC. NREL also started the process towards a second CRADA with Proton Onsite, a leading manufacturer of polymer electrolyte membrane electrolyzer systems. The focus of this CRADA will revolve around advanced grid integration techniques, increasing system efficiency, and improved coupling with renewable sources of electricity.

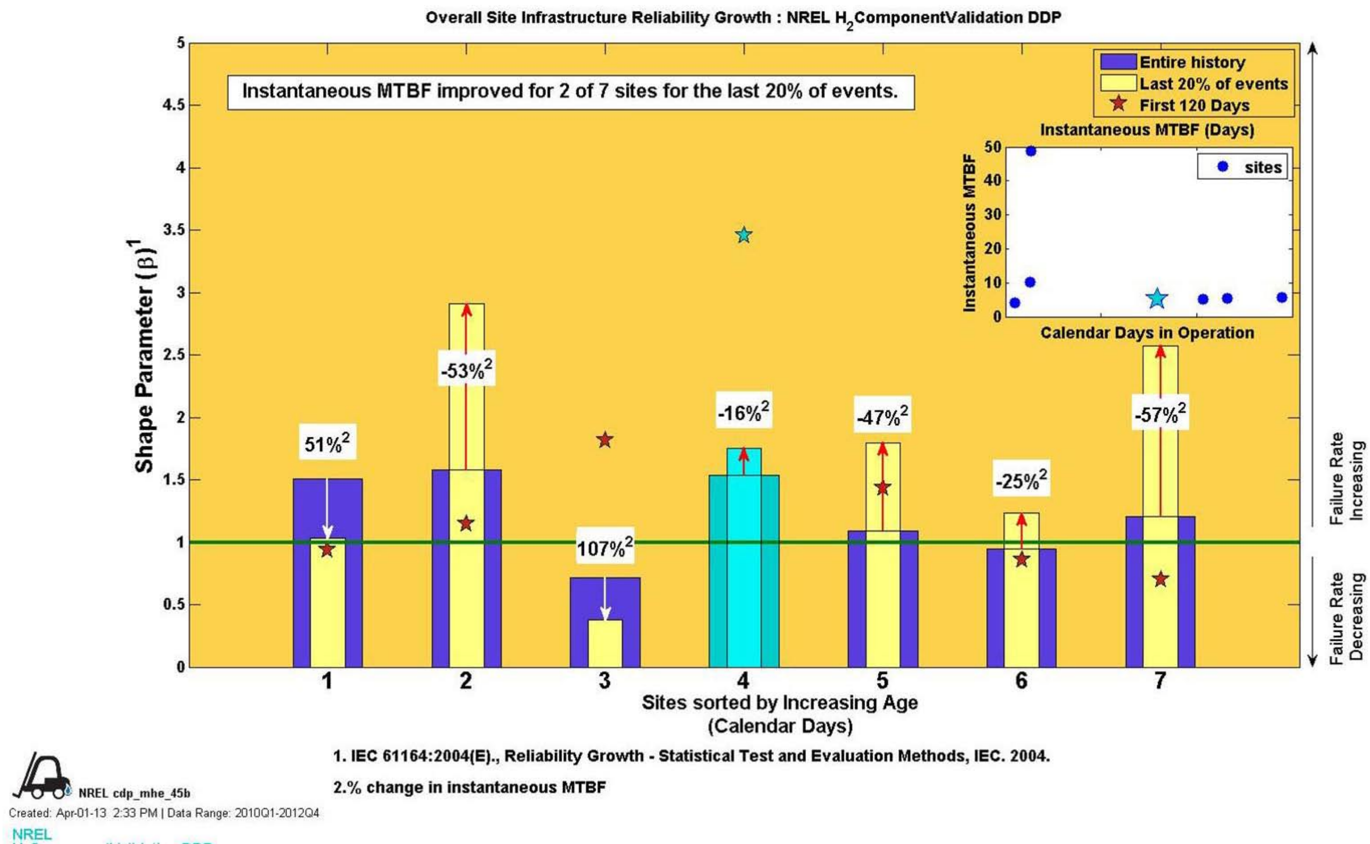
Figure 1 shows the results of reliability tracking at the Hydrogen Component Validation project, as compared to other 350-bar stations for which NREL collects data. Values of the shape parameter above 1 indicate an increasing failure rate, while those below 1 indicate a decreasing failure rate. The rate of failures at the Hydrogen Component Validation project is increasing as a result of its mission to provide highly accelerated life testing of hydrogen components, yet its shape parameter is within the range of other stations its age, indicating that the results, while accelerated, are relevant.

A pneumatically-driven hydrogen gas booster was operated with an accelerated duty cycle and required a rebuild after 200 hours of operation. It was at this point that the high-pressure seals were no longer building pressure above about 3,500 psig, but the seals didn't fail completely. The manufacturer was contacted after the seals were determined to be ineffective and indicated that this situation was very rare after this short duration. They also recommended replacement of both sets of seals and checking the valves.

Worn high-pressure seals leak into a 'dead zone' where the hydrogen gas is ported out a vent. The premature wearing of the seals is attributed to the extremely cold operational conditions the gas booster faced during the first 200 hours of operation—namely, the winter months of December 2012 and January 2013. The gas booster is mounted outdoors in an enclosure but has no heating or cooling to keep it within any temperature range.

The manufacturer (MaxPro Technologies) has indicated that the operational temperature isn't specified, but requires the dew point of the drive air remain below ambient to avoid freezing of the input drive mechanism and vent leak-off port. To assure dry drive air, NREL added an active cooler at the output of the 20-horsepower air compressor to reduce the dew point of the air that drives the gas booster. In addition, a 120-gallon buffer tank was added to reduce the cycling of the compressor.

One significant lesson learned from this initial high-pressure seal rebuild event is that, with the right system controls (e.g., hand valves) and proper analysis equipment (e.g., graduated cylinder), the high-pressure seal degradation can be monitored at the leak-off port. NREL installed the proper system controls and created a process to monitor seal integrity. Full details to these findings will be provided in the DOE CPS 58055 Milestone Report which will be available at the end of August 2013. Figure 2 shows the compressor flow rate versus outlet pressure. The data reveal that the high-pressure seals required replacement because they were not capable of compressing hydrogen above 3,500 psig.



MTBF - mean time between failure

FIGURE 1. NREL's Detailed Data Product Comparing the Hydrogen Component Validation Project

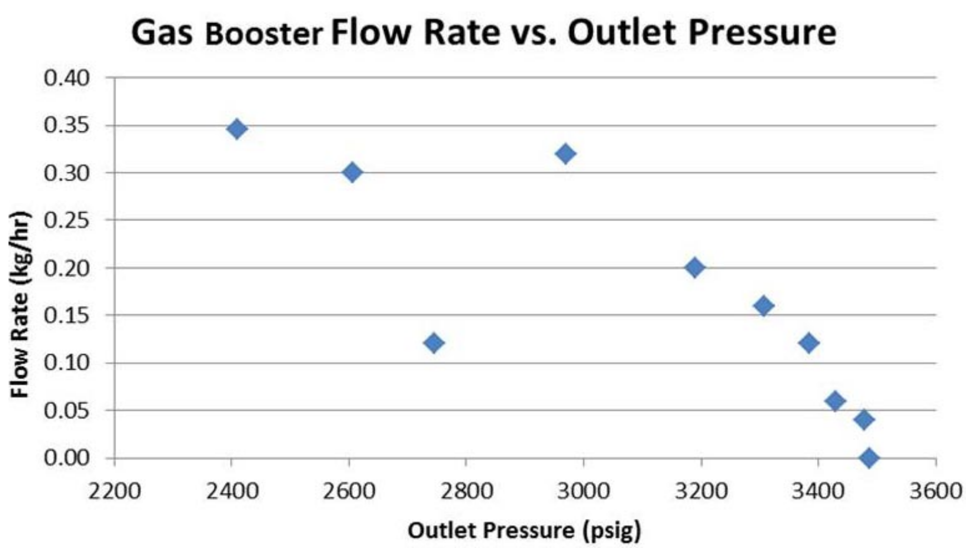


FIGURE 2. Hydrogen Flow Rate versus Gas Booster Outlet Pressure just before Seal Replacement

A work for others project with California's Department of Food and Agriculture, Division of Measurement Standards, allowed the addition of high-pressure storage (13,500 psig) from FIBA Technologies. In addition, two new high-pressure piston gas boosters, from Hydraulics International, were procured using NREL overhead budget from the Transportation and Hydrogen Systems Center. Performance and maintenance of these new systems will be tracked alongside the existing system components.

CONCLUSIONS AND FUTURE DIRECTION

NREL, using various funding mechanisms, expanded the capabilities of the Hydrogen Component Validation project. NREL established a CRADA with PDC Machines and is finalizing another with Proton Onsite. Both agreements will focus on improving their equipment reliability and validate system performance. Tracking of reliability data shows that while the project is successful in accelerating failures of the components under test, the failure rates are within reason for other stations of its type and age and are therefore relevant. A pneumatically-driven hydrogen gas booster was operated with an accelerated duty cycle for 200 hours before rebuilding of the high-pressure seals was required. It was at this point that these seals were no longer building pressure above about 3,500 psig. A process was established to periodically monitor the integrity of the high-pressure seals to better predict the next maintenance event.

In the coming year the team will complete the following:

- Track and evaluate performance of multiple piston-type gas boosters from different manufacturers under an accelerated duty cycle.
- Monitor system faults and maintenance and analyze performance of Xcel Energy/NREL renewable electrolysis, compression, storage, and refueling demonstration project.
- Follow through with CRADAs established in FY 2013 and expand industry involvement in the validation testing being conducted at NREL.