V.A.1 Analysis of Laboratory Fuel Cell Technology Status – Voltage Degradation

Jennifer Kurtz
National Renewable Energy Laboratory (NREL)
1617 Cole Blvd.
Golden, CO 80401
Phone: (303) 275-4061
E-mail: jennifer.kurtz@nrel.gov

DOE Manager
HQ: Kathi Epping Martin
Phone: (202) 586-7425
E-mail: Kathi.Epping@ee.dog.gov

Project Start Date: July, 2009
Project End Date: Project continuation and direction determined annually by DOE

Fiscal Year (FY) 2011 Objectives

- Benchmark state-of-the-art fuel cell durability.
- Leverage analysis experience from Fuel Cell Vehicle Learning Demonstration project.
- Collaborate with key fuel cell developers on the analysis.

Technical Barriers

This project addresses the following technical barriers from the Fuel Cells section of the Fuel Cell Technologies Program Multi-Year Research, Development and Demonstration Plan:

(A) Durability

Technical Targets

This project is conducting an independent assessment of current laboratory fuel cell stacks and systems durability. The analysis, applied uniformly on all data sets, studies the projected operation time to 10% voltage drop. All results are aggregated to protect proprietary information and reported on by the expected application.

FY 2011 Accomplishments

- Published three composite data products (CDPs) on operation time and projected operation time to 10% voltage drop statistics, projected operation time sensitivity to voltage drop levels, and comparison of automotive lab and field durability projections:
  - Automotive
    - Average projected operation hours to 10% voltage drop ~4,000 hours.
    - Maximum projected operation hours to 10% voltage drop ~12,000 hours.
  - Backup
    - Average projected operation hours to 10% voltage drop ~3,300 hours.
    - Maximum projected operation hours to 10% voltage drop ~7,000 hours.
  - Forklift
    - Average projected operation hours to 10% voltage drop ~13,000 hours.
    - Maximum projected operation hours to 10% voltage drop ~21,000 hours.
  - Stationary
    - Average projected operation hours to 10% voltage drop ~17,000 hours.
    - Maximum projected operation hours to 10% voltage drop ~41,000 hours.
- Analyzed fuel cell stack and system data in four application categories and from eight fuel cell developers.
- All data included many proton exchange membrane (PEM) fuel cells and solid oxide fuel cells (SOFCs) of full active area short stacks and full stacks with systems
- Shared all detailed data analysis results with data providers.

✧ ✧ ✧ ✧ ✧

Introduction

The DOE has funded significant research and development activity with universities, national laboratories, and the fuel cell industry to improve market competitiveness of fuel cells. Most of the validation tests to confirm improved fuel cell stack performance and durability (market competitiveness) are completed by the research organizations themselves. Although this allows the tests to be conducted by the developers most familiar with their specific technology, it also presents a number of challenges in sharing progress publicly because test conditions and data analysis take many forms, and data collected during testing are often considered proprietary.

NREL is benchmarking the state-of-the-art fuel cell performance, specifically on durability, through independent assessment of current laboratory data sets. The data processing, analysis, and reporting capitalize on capabilities developed in DOE's Fuel Cell Vehicle Learning Demonstration. Fuel cell stack durability status is reported annually and includes a breakdown of status for different applications. A key component of this project is the collaborative effort with key fuel cell developers to understand what is being tested in the lab, study analysis results, and expand the included data sets.

Approach

The project involves voluntary submission of data from relevant fuel cell developers. We are contacting the fuel cell developers for multiple fuel cell types to either continue or begin a data sharing collaboration. A continuing effort is to include more data sets, types of fuel cells, and developers.

Raw and processed data are stored in NREL's Hydrogen Secure Data Center. Processing capabilities are developed or modified for new data sets and then included in the analysis processing of NREL's Fleet Analysis Toolkit. The incoming raw data may be new stack test data, or it may be continuation of data that has already been supplied to NREL. After the raw data are processed, the results are analyzed with particular attention to durability and operating conditions. Each individual data set has a set of data figures that are shared with the data provider and used to create the CDPs. CDPs are designed to report on the technology status without revealing proprietary information.

Results

This fuel cell stack durability analysis grew in the number of data sets, applications, fuel cell types, and the details published. Results published in June 2010 were the second update for this analysis effort, and the next analysis update is scheduled for July 2011. In the last published data set, four applications were covered, eight fuel cell developers supplied data (more than one data set in many cases), and the data sets covered PEM and SOFC stack testing. The analyzed data sets are from lab testing of full active area short stacks (e.g, stacks with fewer cells than the expected full power stack) and test systems with full power stacks. The data sets also vary from one to the other in how the stack/system was tested. Data was generated between 2004 and early 2010 from different testing methods that included constant load, transient load, and accelerated testing. The variability in test conditions and test setups create a group of data that can be difficult to compare. Additional breakdown of the data sets is an important aspect of future work and is dependent on the accumulation of more data sets in order to not reveal data supplier contribution to the results or proprietary data.

Fuel cell durability is studied at a design specific current point and measured against a target of 10% voltage drop from beginning of life. The 10% voltage drop metric is used for assessing voltage degradation with a common measurement, but the metric may not be the same as end-of-life criteria and does not address catastrophic failure modes. Figure 1 is an aggregated set of results separated by application and identifies the percentage of short stacks and how many data sets are still operating (at the time of the results) for each application. Each application has the average, maximum, 25th and 75th percentiles values

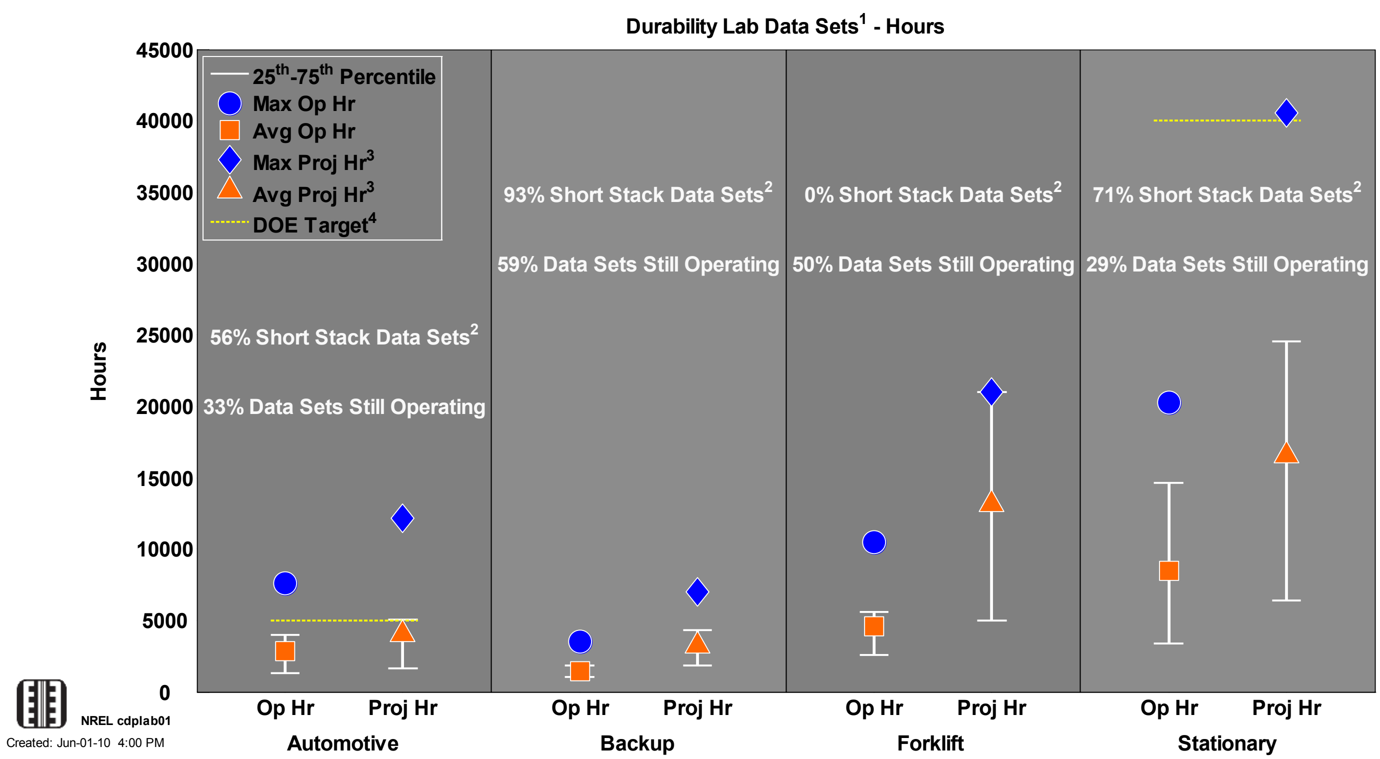

FIGURE 1. Fuel Cell Operation Hours and Projection Hours to 10% Voltage Drop by Application

identified for the operation hours and the projection hours to 10% voltage drop. Table 1 summarizes the average values highlighted in Figure 1.

TABLE 1. Summary of Average Operation Hour and Average Projection Hour to 10% Voltage Drop by Application

Application	Average Operation Hour	~Average Projection Hour to 10% Voltage Drop
Backup	1,424	3,300
Automotive	2,865	4,000
Forklift	4,573	13,000
Stationary	8,438	17,000

The 10% voltage drop level is not necessarily a measurement for end-of-life or even significant reduction in performance. Figure 2 depicts the sensitivity of each application's projected hours to a varying voltage degradation level. Each curve represents the average for each application, but the graph does not imply that all stacks will (or do) operate at these voltage degradation levels. In the analysis, the projection may be limited by the demonstrated operation hours to minimize extrapolations. This limit is why the application average curves flatten out at the higher voltage degradation levels.

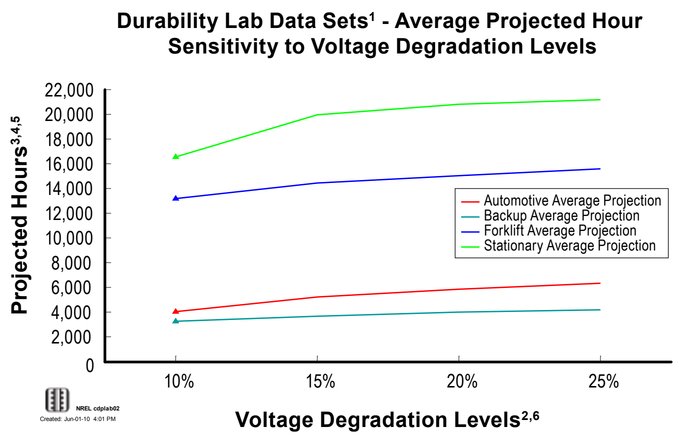

FIGURE 2. Durability Projection Sensitivity to Measured Voltage Degradation Levels

Another avenue for analysis is the comparison of data generated from testing in the lab and real-world operation. Figure 3 is the first phase in this comparison analysis. In addition to this analysis of lab data sets, NREL is also studying the performance of many fuel cell applications in real-world settings. Improvements were demonstrated in the field for Generation 2 fuel cell vehicles as seen in Figure 3. A large improvement is also observed when comparing the

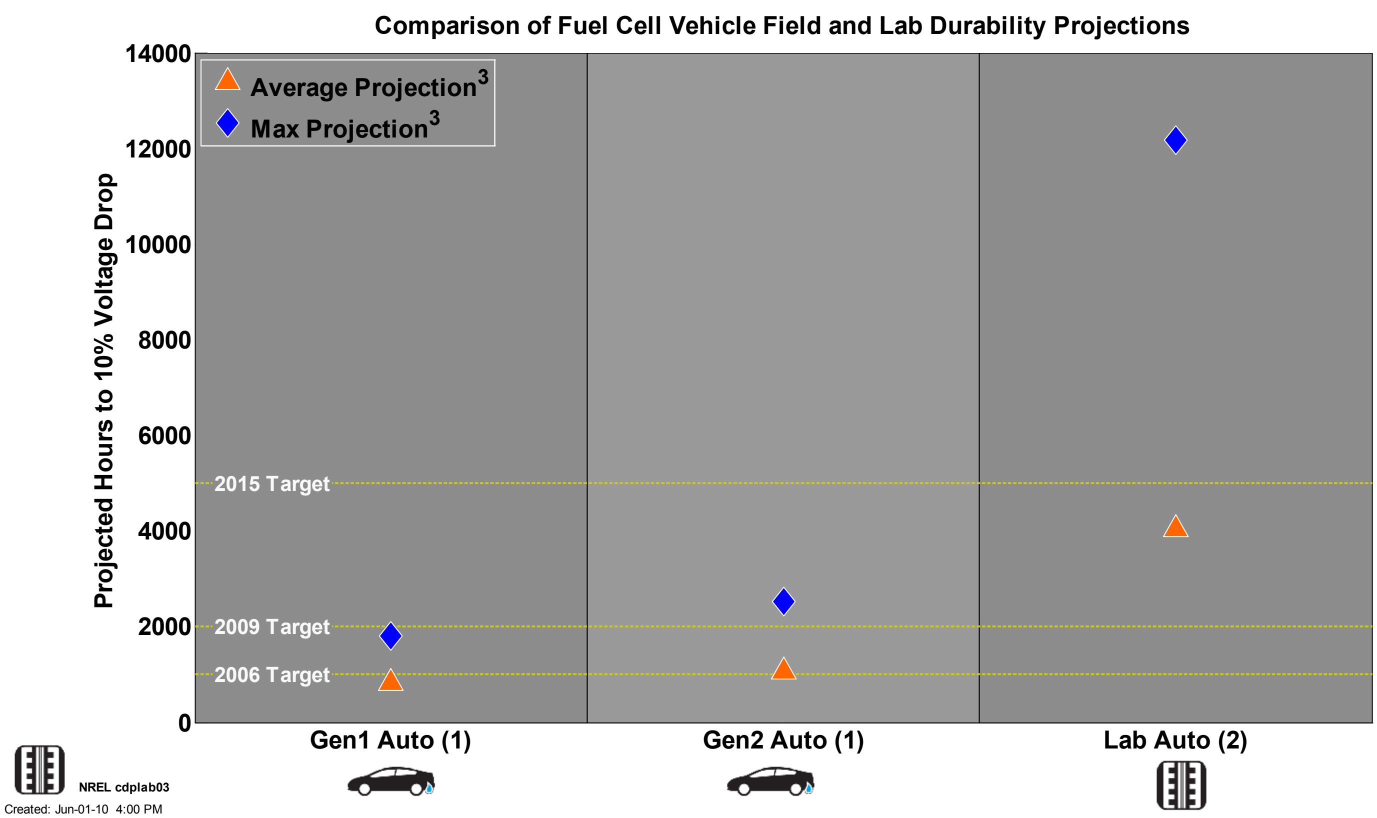

FIGURE 3. Automotive Fuel Cell Durability Projection Comparison between Lab and Field Data

Generation 2 field data with the lab data results. There are a number of potential explanations for the improvements: 1) improvements in technology generation and performance; 2) testing conditions; 3) 56% of the lab data sets are short stacks, and none are integrated into a vehicle; and 4) data providers in the lab category are not all the same as the data providers for the field category.

Conclusions and Future Direction

This analysis effort highlights the positive progress made by the fuel cell developers with the state-of-the-art fuel cell stacks and applies a uniform analysis method to aggregate and report on the results. Results highlight the difference in performance between applications to meet specific market needs as well as the needs for expansion of the results for more details and categories, such as accelerated testing. Data are supplied voluntarily and an important aspect of this project is the collaboration effort to study the data, project durability, and report on the results without revealing proprietary data. Eight fuel cell developers have already supplied data and other fuel cell developers are expected to add data for the next analysis and reporting cycle.

Planned future work is as follows:

- Update analysis results through published CDPs (July 2011).
- Continue collaboration and data sharing with existing data suppliers and other fuel cell developers (on-going).
- Accumulate more data to allow for new and more detailed CDPs (on-going).
- Expand comparison of durability projections between lab data and field data (July 2011).

FY 2011 Publications/Presentations

1. Kurtz, J.; Wipke, K.; Sprik, S. "Fuel Cell Technology Status – Voltage Degradation," presented at DOE's Annual Merit Review May 12, 2011.

2. Kurtz, J.; Wipke, K.; Sprik, S. "Analysis Results of Lab and Field Fuel Cell Durability." presented at 2010 Fuel Cell Seminar October 20, 2011.