Data Analytics Applied to SOFC Durability Time-series Datasets

Hanke Gu, Celeste Cooper, Roger H. French, and Mark R. De Guire*
Case Western Reserve University

*) Mark De Guire, mrd2@case.edu, 216-368-4221

Abstract

Durability testing of solid oxide fuel cells (SOFCs) provides extensive time-series datastreams (including operating temperature, cathode and anode atmosphere, test conditions, output voltage, current density, area-specific resistance (ASR) variables) that can serve as predictors of the cell's performance, either through direct action or correlated phenomena. These datasets lend themselves well to data-science analytics approaches for extracting greater understanding of the relationship between test conditions (predictors) and cell performance (response) over time.

Results from SOFC button-cell tests for up to 624 hours of operation under conventional and accelerated conditions have been analyzed using data analytics code written in R, the statistical programming language, to discern recurring patterns in cell output that are often overlooked in other studies.

Here we report two such patterns: fluctuations in cell output voltage with 24-hour periodicity (diurnal cycling behavior); and the effects on cell output from intermittent diagnostic tests (linear sweep voltammetry (LSV) and electrochemical impedance spectroscopy (EIS)). We find diurnal fluctuations in nearly every test run in this project, and we speculate here on possible causes. Possibly more disruptive are discontinuities in cell performance after many of our LSV/EIS tests. Ultimately, the goal of this approach is to use data-driven time-series analytics to better understand and identify the underlying mechanisms that lead to changes in cell performance during long-term testing, and possibly to detect sources and signatures of cell degradation at early stages so that remedial action might prolong the cell's operational lifetime.

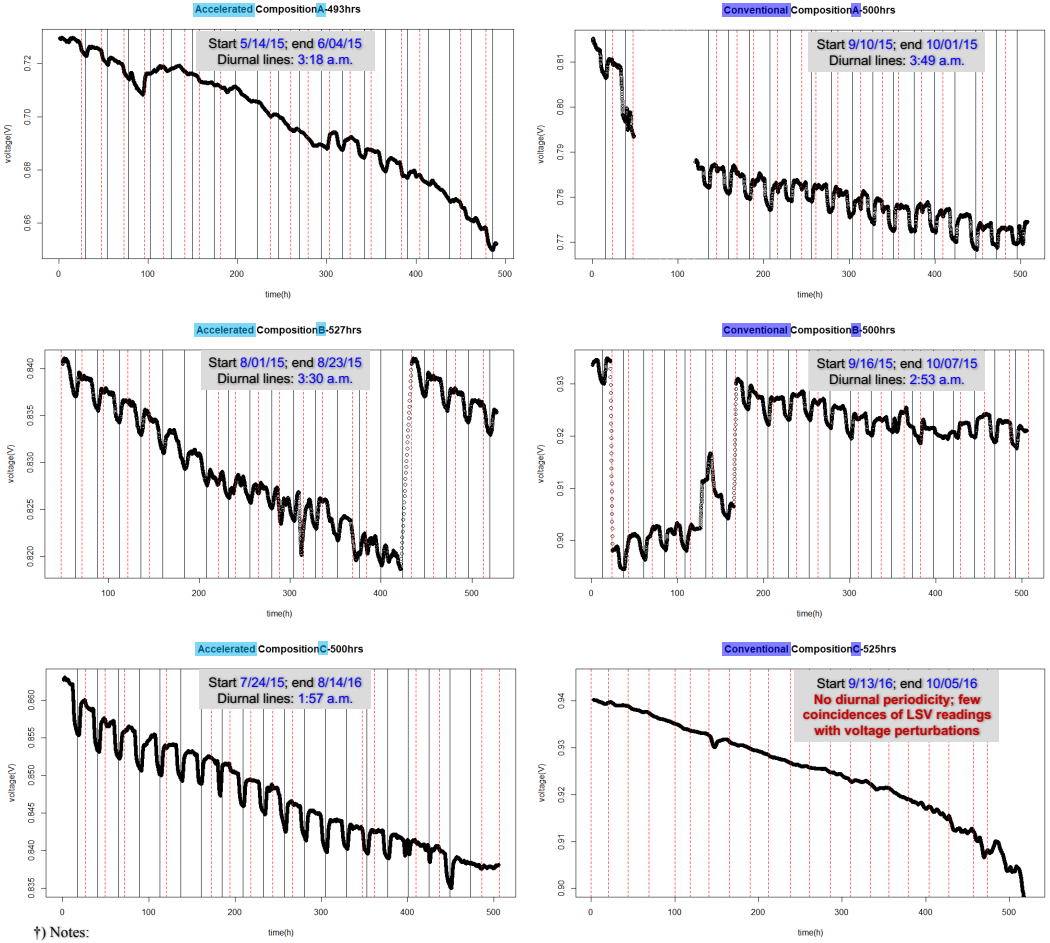
Introduction

- **Why choose Rstudio?**
  - Faster computation
  - Easier to find and fix errors
  - Reading and writing data to and from R
  - Easy to share – rmd files can be converted to pdf, HTML, and Word documents.
  - Free and open source – thousands of packages to improve its functionality
  - Advanced statistics capabilities
- **Smoothing method: rolling averages**
  - Average voltage readings over a period of ~100 minutes (~50 min before and after)
  - "Shifting forward" – excluding the first number of the series and including the next value in the dataset
  - R package "zoo" – "rollmean," "rollapply"

Results:† cell voltage (smoothed) vs. time; three LSM cathode compositions; accelerated vs. conventional conditions

Diurnal periodicity – black lines placed every 24 h after first minimum in voltage; **LSV/EIS readings** (intermittent) – red dashed lines

Accelerated testing: 1000 °C, 0.76 A cm^{-2} | **Conventional testing: 900 °C, 0.38 A cm^{-2}**



†) Notes:

- All cells were circular, planar, 8YSZ-electrolyte-supported button cells with identical Ni/8YSZ anodes and one of three LSM/8YSZ cathode compositions.
- All tests used ambient air on the cathode side and humidified hydrogen at 50 sccm on the anode side.
- None of the tests shown here occurred during changes to or from daylight savings time.

Discussion

		24-h lines match voltage minima	LSV lines match voltage perturb'ns
cathode A	accel'd, 493 h	**11/20**	**13/18**
	conv'l, 500 h	**18/18**	**15/16**
cathode B	accel'd, 527 h	**19/20**	**14/17**
	conv'l, 500 h	**17/21**	**15/19**
cathode C	accel'd, 500 h	**17/20**	**10/15**
	conv'l, 525 h	**n/a**	**4/21**

Conclusions

- **Five of six** datasets showed diurnal periodicity, with voltage minima between **2 and 4 a.m.**
- In tests showing periodicity, **83%** of diurnal lines (**78%** accelerated, **90%** conventional) **matched voltage minima.**
- Overall, **69%** of LSV lines **matched voltage perturbations** (dips, peaks, shifts) (**79%** excluding the conventional C 525-h test).

Ongoing & Future Studies

- Does the cyclic diurnal response correlate with ambient conditions (temperature, % relative humidity, barometric pressure)?
- LSV/EIS readings entail abrupt switching between zero and near-peak power. Does this accelerate cell degradation?
- Does cross correlation function (CCF) analysis show coupling of the system's responses (to LSV readings and diurnal conditions) with the time intervals between those stimuli?

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