Institute of
Engineering Thermodynamics

Investigation and Comparison of Different Performance Recovery Procedures for Polymer Electrolyte Membrane Fuel Cells

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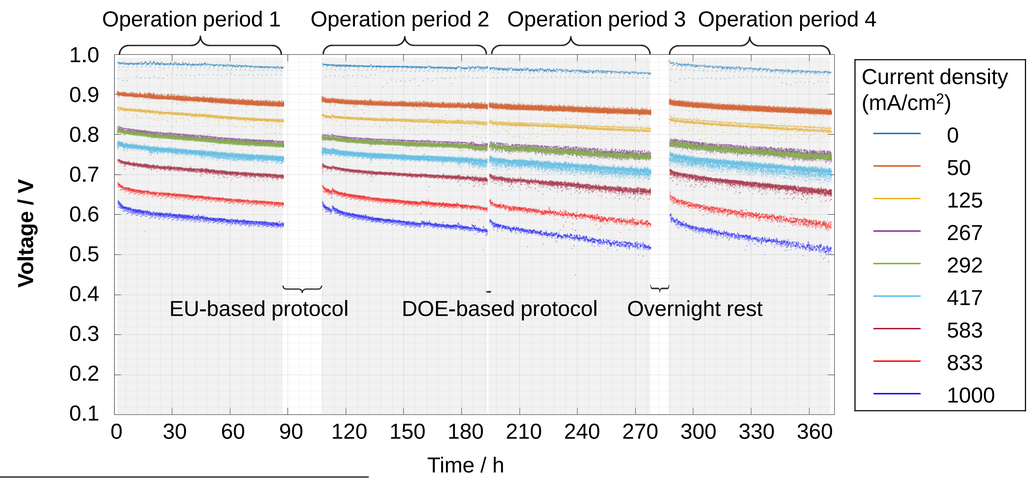
Motivation

It is of great importance to distinguish the reversible performance decay during fuel cell operation since its recovery or mitigation can substantially extend fuel cell lifetime. However, the recovery of reversible losses depends on specific recovery procedures and operation history of the cell. This work evaluates specific recovery procedures and its impact on cell performance and further proposes approaches about how to describe efficiency of a recovery procedure .

Approach

- A durability test was performed consisting of four operation periods using FC-DLC cycles with a single PEMFC and a commercial MEA. After each operation period an EU-based protocol [1], DOE-based protocol [2] and overnight rest [3] were applied as recovery procedures.
- Polarization curves and EIS measurement were used for characterization.



EU-based Protocol

Step	Cathode	Anode	Duration /min
1 H_2 soak	Shut off air; Close outlet	H_2 2 L/min until U<0.1V	40
2 N_2 purge	N_2 2 L/min		30
3 Air purge	Air 2 L/min		30
4 Cool down	Cool down		8 h
Total Duration	10 h 10 min		

DOE-based Protocol

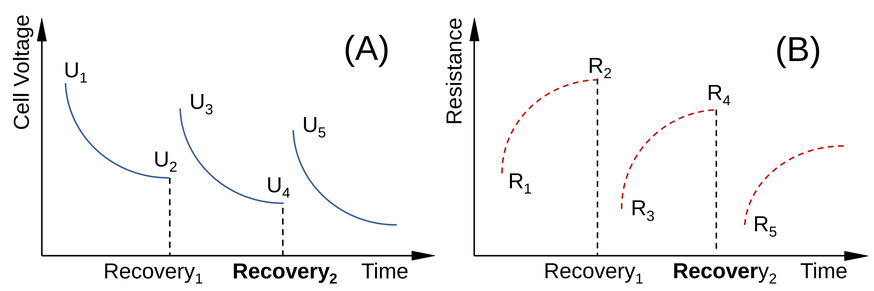
Step	Cathode	Anode	Duration /min
1 N_2 purge	N_2 4 L/min	N_2 2 L/min	2
2 Air soak	Air 4 L/min	Shut off	15
3 N_2 purge	N_2 4 L/min	N_2 2 L/min	2
4 H_2 soak	Shut off N_2	H_2 2 L/min	10
Total Duration	29 min		

Overnight Rest

Step	Cathode	Anode	Duration /h
1 Shut down	Shut off air; Close outlet	Shut off H_2; Close outlet	
2 Cool down	Shut down the test bench		8
Total Duration	8 h		

Evaluation Methodology

The schemes of the cell voltage (A) and resistance (B) change during a fuel cell durability test with interruption of two recovery procedures.

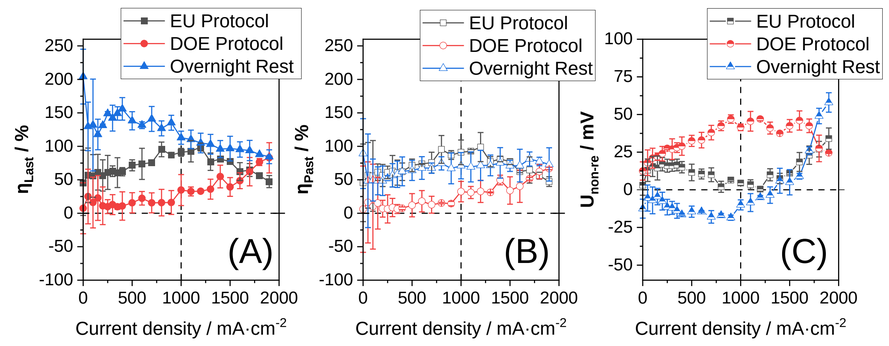


Taken the analysis of Recovery$_2$ as example, the following values should be investigated to evaluate the efficiency of a recovery procedure:

$U_{re} = U_5 - U_4$	*Recovered voltage*
$U_{non-re} = U_3 - U_5$	*Non-recovered voltage*
$\eta_{Last} = \frac{U_5 - U_4}{U_3 - U_4}$	*Relative recovery related to the recovery of last operation period*
$\eta_{Past} = \frac{U_5 - U_4}{U_1 - U_4}$	*Relative recovery related to the beginning of test*
$\Delta R_{Last} = R_4 - R_3$	*Increased resistance within the last operation period*
$\Delta R = R_4 - R_5$	*Reduced resistance by the recovery$_2$*

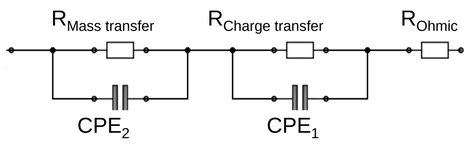
Experimental Results

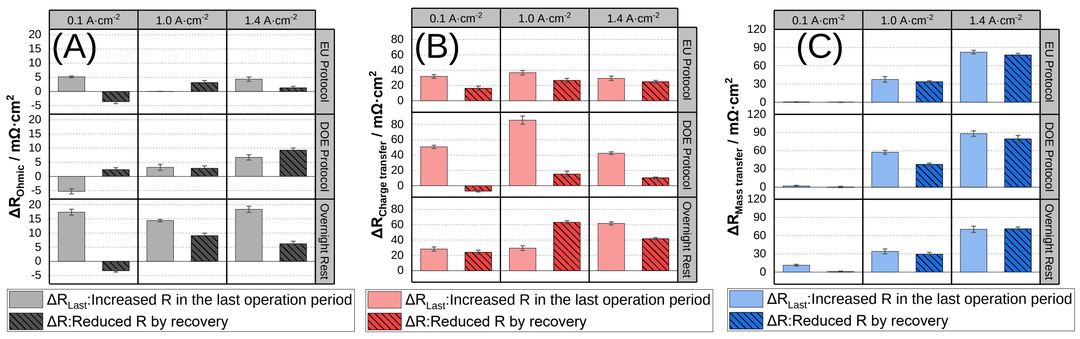
η_{Last} (A), η_{Past} (B) and U_{non-re} (C) after each recovery procedure calculated by the polarization tests results.



- **EU-based protocol and overnight rest lead to similar η_{Past}**
- **DOE-based protocol exhibits lower η_{Past} at low current density range**
- **At high current density range all three procedures lead to similar results**
- **η_{Last} contains additional effect due to accumulated reversible losses from previous (inefficient) recoveries**

The equivalent circuit model used for fitting the fuel cell EIS data



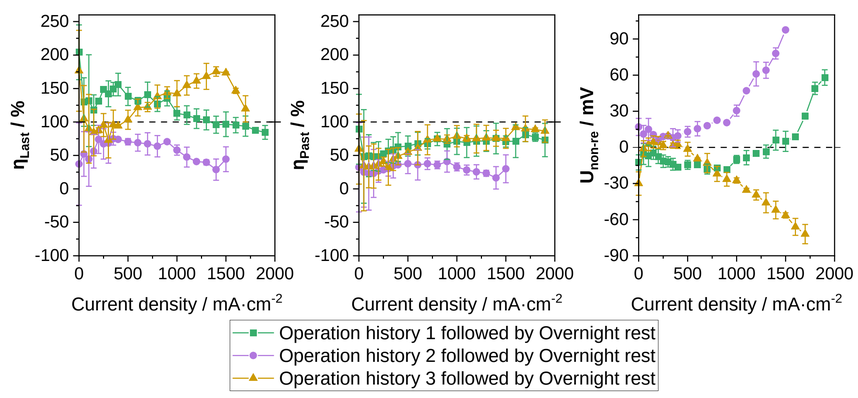


Change of ohmic, charge transfer and mass transfer resistance during each operation period and after each recovery.

- **DOE-based protocol exhibits less recovery with respect to charge transfer resistance than the other two procedures**
- **All procedures show similar recovery of mass transfer resistance**

Effect of Operation History

- The importance of the operation history in a durability test was identified with two additional experiments using overnight rest.



Three durability tests have the same number of operation periods and all of them take overnight rest as the third recovery protocol, whereas all the former recovery protocols are different.

- **The effect of operation history is evident when comparing different operation modes with a recovery procedure, which demonstrates the complexity of the fuel cell recovery procedures.**

References:
[1] Tsotridis, Georgios, et al. "EU harmonised test protocols for PEMFC MEA testing in single cell configuration for automotive applications." JRC Science for Policy report 27632 (2015).
[2] DOE, US. The Fuel Cell Technologies Office Multi-Year Research, Development, and Demonstration Plan. Technical report: US Department of Energy, 2016.
[3] Gazdzick, Pawel, et al. "Evaluation of reversible and irreversible degradation rates of polymer electrolyte membrane fuel cells tested in automotive conditions." Journal of Power Sources 327 (2016): 86-95.

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