Development of an Optimized Experimental Design for Modeling Reversible and Irreversible Degradation of PEM FCs based on Realistic Driving Cycles

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Motivation

- **Operating Strategy** has a significant influence on the **degradation behavior** of PEM Fuel Cells
- Accelerated Stress Test (AST) based degradation studies are **limited transferable** to realistic driving cycles [1, 2]
- **“Realistic”** driving Cycle studies [3, 4]:
  - Focus on individual stressors, but no cross-dependencies
  - Focus mainly on automotive application
  - Limited distinction between reversible and irreversible degradation
  - Little focus on power-controlled operation

Objective

Development of an experimental framework for the efficient parametrization of degradation models under realistic operating conditions

- Minimization of experimental time
- High model quality & predictive capability
- Consideration of realistic drive cycles and regeneration conditions

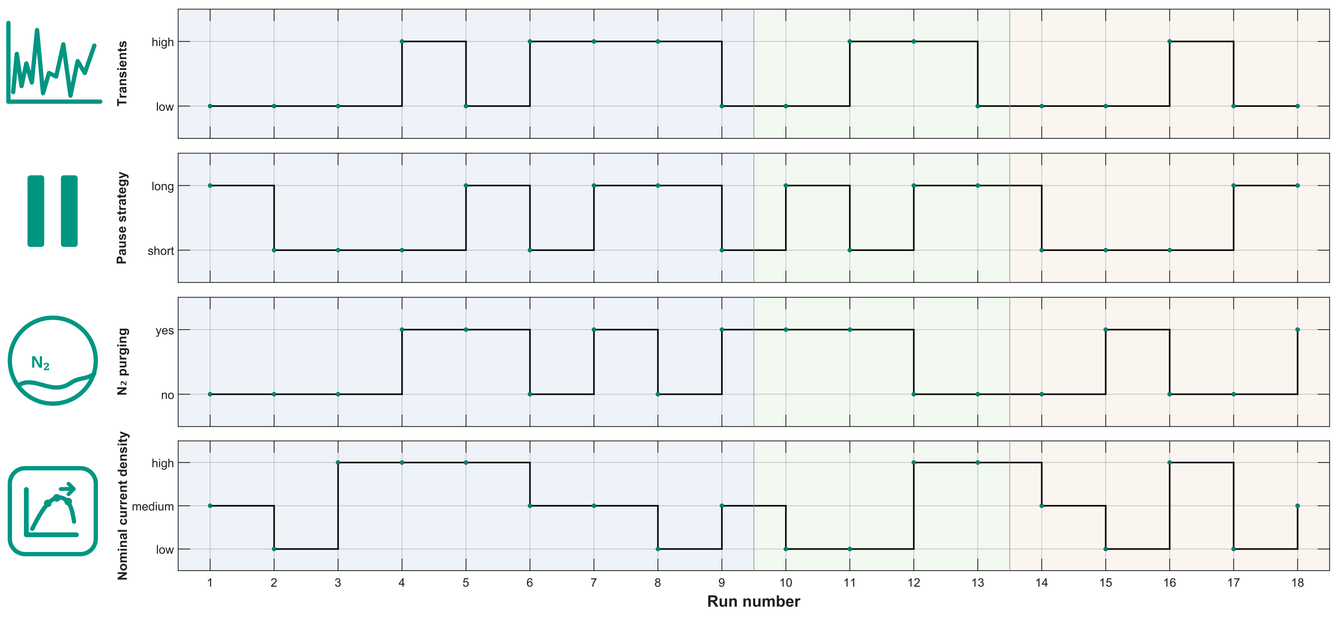
Basis for the development of validated degradation models and the derivation of optimized operating strategies

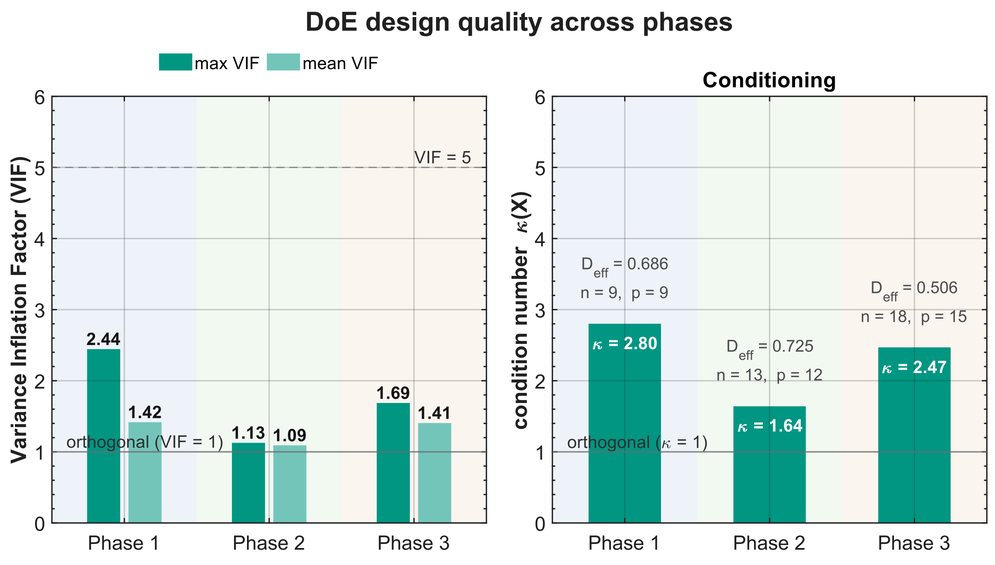
Methodology Overview



Realistic load profile → Design of Experiments (DoE): D-optimal design → Long-Term tests under realistic auxiliary (Balance of Plant) conditions → Reference & regeneration characterization → Degradation model of reversible & irreversible effects

Experimental Design & Evaluation





Phase 1	Phase 2	Phase 3
Identification of main effects and interactions between N2 Purging, Pause Strategy & Transients	Identification of linear Interactions between all parameters	Identification of nonlinear behavior of nominal current density

Design stays near-orthogonal at every phase (max VIF ≤ 2.4, κ ≤ 2.8) → unbiased, low-variance effect estimates even at the Phase-1 stop, enabling robust early termination under limited testbench time.

Sources

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[4] Bove, R., Malkow, T., Saturnio, A. u. Tsotridis, G.: PEM fuel cell stack testing in the frame-work of an EU-harmonized fuel cell testing protocol: Results for an 11kW stack. Journal of Power Sources 180 (2008)

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