Feasibility Study of an ML-Based Evaluation System for Quality Assessment of MEA Cells in Industrial Manufacturing

Background and Problem Statement

In the current production environment, MEA cells (Membrane Electrode Assembly) are assessed for quality using established methods. The conventional use of fixed thresholds on easily interpretable parameters, such as voltage, as a quality metric for MEA cells entails methodological limitations, as it disregards complex electrochemical interactions, material heterogeneities, and degradation pathways that require comprehensive, multidimensional analysis to ensure robust and reliable quality assessment.

Given the availability of various measurement parameters collected during the production process, the use of advanced machine learning methods becomes a viable option. The central question is whether an ML-based approach can replace or complement the existing evaluation methodology while enabling an improved or comparable assessment of cell quality.

The challenge lies in formulating a practical methodology that considers the specific requirements of the production environment while ensuring scientific rigor.

Objective of the Thesis and Expected Results

The main objective of this thesis is to conduct a research-oriented feasibility study on the development of an ML-based evaluation system for assessing the quality of MEA cells. The research aims to systematically investigate whether and in what way machine learning methods can be applied in this domain and to identify suitable approaches for implementation.

Expected results:

- Comprehensive understanding of the application domain and relevant influencing factors
- Conceptual design of an ML-based evaluation approach
- Implementation of a prototype or proof of concept
- Evaluation of different ML methods regarding their suitability
- Documentation of insights, including identified challenges and limitations

It is acknowledged that the outcome may include the identification of fundamental limitations, potentially demonstrating that an ML-based approach is unsuitable for this application. Such findings are considered equally valuable for guiding future research and development efforts.

Methods and Approach

The thesis follows a structured, research-oriented procedure:

1. Understanding the Application Domain

- Analysis of the current evaluation methodology
- Identification of relevant process parameters (e.g., electrical characteristics, operating conditions)
- Consideration of the production environment (constant vs. variable parameters)

2. Conceptual Design & Methodologies

- Development of an approach for parameter aggregation
- Definition and normalization of relevant metrics
- Investigation of different approaches to establish a reference basis (ground truth)

3. Implementation

- Prototypical implementation of selected ML methods
- Data preprocessing and feature engineering
- Training and optimization of the models
- Monitoring training processes using an MLOps tool

4. Testing & Validation

- Evaluation of the developed approaches
- Comparison of different methods
- Critical assessment of the results and overall feasibility
- Derivation of a feasibility evaluation

Creativity, Variations, Innovation (Optional)

The thesis allows room for exploratory investigations, such as trying different modeling approaches, evaluation procedures, or methods for establishing a ground truth. The specific choice of methods remains deliberately open to enable flexibility based on new insights gained during the work.

Additional Remarks (Optional)

- The work has an exploratory character—negative or unexpected results are scientifically valuable.
- Flexibility in the choice of methods depending on data availability and initial findings.
- Possibility to adjust the focus of the thesis based on intermediate results.