Deep learning and neural network approaches for Solid Oxide Cell based Electrochemical Impedance Spectroscopy analysis

Master Project (30 ECTS)

Administrative:

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Location: Sion or remotely (travel allowance offered)
Remarks: If interested, please send your CV, with a short motivation letter, to Hangyu Yu.

Project description:

In the context of global climate change, numerous countries have launched their targets and routes toward "Carbon neutrality", which leads to the booming of low-carbon-emission and efficient renewable energy technologies. Solid oxide cell (SOC) technology is favored as one promising clean energy application due to (1) the high efficiency (>60% in fuel cell mode, >80% in electrolysis mode), (2) the capability of heat integration under high operating temperature (>650 °C), (3) compact system design, and (4) flexible mode switch between fuel cell and electrolysis modes. To better understanding the electrochemical mechanisms inside the cell, electrochemical impedance spectroscopy (EIS) is generally applied during the operation. The Group of Energy Materials (GEM) has now a great amount of SOC-based EIS data in multiple scales (cell, short stack, and whole stack) and multiple types (anode supported cells and electrolyte supported cells). However, due to the different cell geometry and measurement noise, it is hard to completely decouple the electrochemical processes.

Conventionally, distribution of relaxation times (DRT), equivalent circuit models (ECM), and complex non-linear least square (CNLS) fit methodologies are applied to identify the behavior of different electrochemical processes, for example, the gas conversion process, the O^{2-} surface exchange process, the gas diffusion processes in two electrodes and the electrode charge transfer processes. However, the results have been not convincing due to measurement noise and the nature that different electrochemical processes can overlap with each other, making the EIS results resemble black box. Instead of pursuing accurate ECMs, deep learning methodology can be considered as a novel approach to address this problem. On the one hand, EIS data has multiple dimensions including impedance, phase and frequency, similar as the audio and image, which has been actively handled by deep learning methods in the past decades. On the other hand, the deep learning approach can be guided by the existing knowledge from the conventional methods, like, DRT, ECM and CNLS fit.

This project aims to study the pathway of using deep learning methodology to analyze the SOC EIS data. Existing EIS dataset from GEM and the partners will be combined with different neural network architectures to gain deeper understanding of the electrochemical processes in SOC.

The following skills are recommended for this project: (1) good knowledge of solid oxide cell technology and electrochemistry, (2) good knowledge of deep learning and neural network methods, (3) coding skills with python, and (4) high-level motivation and ability to working in an autonomous environment.

Your tasks:

1. By literature review, understanding the state-of-art application of deep learning and neural network methods in solid oxide cell-based EIS analysis.

2. Performing data cleaning based on the existing EIS measurements in GEM and the dataset from the literature.

3. Find the most suitable neural network architecture to perform curve smoothing and noise cancellation.

4. Proposing the best neural network architecture to separate different electrochemical processes and quantify their resistances based on the existing knowledge from the conventional methodologies, including distribution of relaxation time, equivalent circuit model, complex non-linear least square fit.