Data access and harmonization: Unlocking the potential of BMS

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Introduction to NEMO

NEMO aims to advance novel and established modelling techniques based on electrochemical impedance spectroscopy (EIS) to their application.

NEMO is lead by Vrije Universiteit Brussel and has partners with expertise in batteries, BMS systems, hard- and software.

Data plays a central role for NEMO – therefore data harmonization is a big topic for us

Data Harmonization for BMS data

Today I will show you data harmonization issues and best practises based on a very useful and common method in batteries:

Electrochemical Impedance Spectroscopy, a technique to measure the electrical response of batteries across different frequencies.

Why it Matters: Provides insights into internal resistance, capacity fade, and degradation.

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Challenges and obstacles

In our project (like many others), three partners gather EIS data: TU Graz, VUB and CSEM. Each of the partners has:

- Different measurement instruments (Manufacturers, types, age)
- Different operators (and those can change too – like students)
- Different types of measurement with different goals
- And typically stores data in a different format!

But we need all data to develop better battery models – how can we do that?

Examples of Challenges: The obvious

Multiple EIS Instruments:

- Gamry, BioLogic, Solartron, and others
- Different data formats, structures, and metadata fields

Diverse CSV and File Structures:

- Metadata in rows vs. columns.
- Different column names, delimiters, and units

Data Processing Inconsistencies:

- Need for standardization across experiments
- Handling missing values and measurement artifacts

Gamry vs. BioLogic:

- Different measurement protocols
- Variability in frequency resolution
- Discrepancies in file output structures

Impact on Data Analysis:

- Difficulties in cross-experiment comparisons.
- Need for manual corrections before processing

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Examples of Challenges: The unexpected

There are not only „technical“ challenges but also those when you work in a multidisciplinary project:

Chemists:

- Store data mostly in the format their EIS system has as standard
- Store data in folders, (somehow) structured
- Mostly don‘t care about data integrity, backups, metadata

IT specialists:

- Don‘t understand what‘s inside the EIS files or what they are about, just see numbers
- Need a clear structure, don‘t like changes in data format
- Are concerned about how the data is kept in good order and not lost

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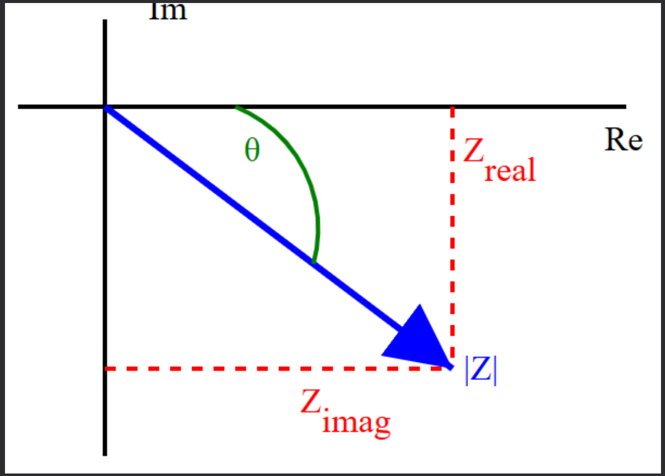
Clear communication is key – best is to have somebody who understands both worlds!

Data representation issues: An example

The impedance value can be represented in two ways:

- A combination of the real and imaginary value
- Or the absolute value and the phase angle

Different data providers store the data in different formats. Essentially the represent the same physical value
Data conversation is important and knowing what can be converted too! – Big challenge in data harmonization



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How do we harmonize data in NEMO

Unified Database Scheme

- Separating metadata from measurements.
- Ensuring relational integrity for comparisons.

Parsing Scripts

- Custom scripts to read and standardize CSV formats.
- Handling missing metadata and incorrect delimiters.
- Converting different impedance representations.

Automating the process

- Python-based pipelines for efficient data handling.
- SQL database for structured storage and retrieval.

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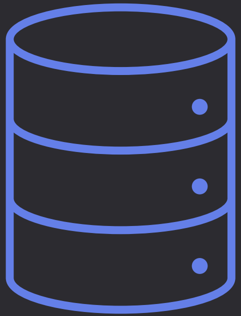
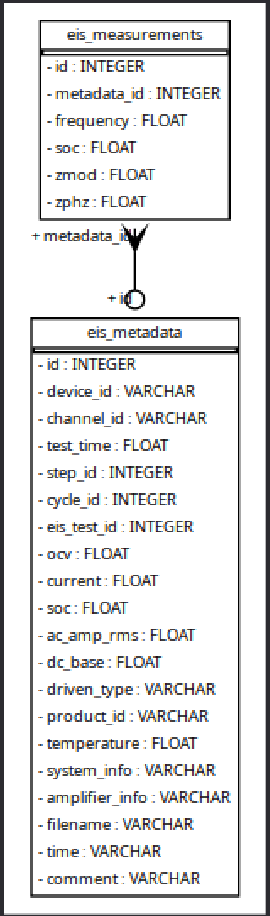
Database Structure for EIS Data

- We store all data in a centralized databse
- - Structured and scalable data management.
- - Enables querying across multiple experiments.



- Schema Design:
- - Separate tables for metadata and measurements.
- - Foreign key for linking experiments.



EIS Data Integration Workflow

- Step 1: Extract metadata from different file formats.
- Step 2: Convert all impedance data to a unified format.
- Step 3: Store in a structured SQL database.
- Step 4: Enable easy querying and visualization.

Data storage: Cloud Architecture

NEMO Cloud is based on Microsoft Azure, a well-known cloud service

TTTech is maintaining a cloud instance for NEMO based on Azure

This cloud instance contains for now:

- Central database (PostgreSQL/TimescaleDB) for data storage
- Cloud File Storage (to upload data like CSVs)
- Serverless data ingestion procedures to store uploaded data in database
- An environment to execute cloud models based on Docker containers

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Data ingestion pipeline

Partner responsible

TTTech responsible

BMS produces data

Sends data

Local server at partner stores timestamped CSVs of the BMS data. Regularly uploads to CSVs to Azure Cloud Storage

Preprocessing and/or local models may also happen here

Upload data

Azure Cloud Storage

Automatic ingestion using serverless functions Conversation

Timescale Database

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Lessons Learned from Data Harmonization

- Common Issues Faced:
  - Inconsistent metadata storage.
  - Missing values requiring interpolation or estimation.
  - Differences in frequency points across datasets.
- Best Practices for Standardization:
  - Using a common naming convention.
  - Automating metadata extraction.
  - Defining a unified impedance representation.

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How to make data accessible

- There is no standardized EIS data ontology
- So we will publish the results at the end of the project in our own ontology

- Data will be saved for long-term accessibility on Zenodo

Key Takeaways

- Data harmonization is essential for meaningful battery model development to have a full picture of the available data
- Standardization efforts reduce analysis time and improve comparability
- One needs to fill the gap between data creators and data users
- Automation helps scale up EIS data handling in research and industry

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Questions?

Thank you for your attention.

Disclaimer

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