European Partnership on Metrology
Call 2025 – Health, Integrated European Metrology, Regulation and Research Potential

Selected Research Topic number: **SRT-n03**
Version: 1.0

Title: Metrology for traceable determination of battery performance

Abstract

Batteries are key enabling components for electromobility and energy storage as countries seek to phase out fossil fuels. The new Batteries Regulation EU 2023/1542 aims to make batteries sustainable throughout their life cycle. It states that compliance tests regarding battery key performance indicators (KPI) should be performed with low uncertainty, whereas presently, these KPIs still lack traceability and uncertainty evaluation. A particular challenge is that these KPIs are not directly measured but derived from models. Proposals are sought to develop a metrological framework for battery KPI uncertainty estimation and new measurement techniques for improved accuracy, as a foundation for future standardisation work.

Keywords

Battery performance, battery key performance indicators, uncertainty evaluation, battery state of health (SoH), battery state of safety (SoS), battery management system (BMS), EU Batteries Regulation, battery metrology.

Background to the Metrological Challenges

Batteries are a fundamental means for energy storage and one of the key enablers for sustainable development, green mobility, clean energy and climate neutrality. It is expected that the demand for batteries will grow rapidly in the coming years, notably for electric road transport vehicles and light means of transport using batteries for traction. The new Batteries Regulation EU 2023/1542 [1] entered into force in 2023 to support the EU's 2050 net zero CO_2 emission targets and calls for a harmonised regulatory framework for dealing with the entire life cycle of batteries that are placed on the market or put into service in the EU.

The Batteries Regulation establishes specific targets for recycled materials and specifies what information must be made available on batteries in the EU. It also establishes explicit guidelines for proper precautions and user responsibility throughout the battery's lifetime. Many of the standards and targets are specified several years in advance, with an intention to impose new standards at a later date via delegated acts. Article 15 of the Batteries Regulation states that compliance tests, measurements and calculations regarding performance and durability, safety, and state of health and expected lifetime, "shall be made using reliable, accurate and reproducible methods which take into account the generally recognised state-of-the-art methods, and the results of which are deemed to be of low uncertainty", and "shall aim to simulate real-life usage". The related metrology to guarantee the reliability of these tests, measurements and calculations with low uncertainty is still largely missing.

The technical report [2] from the European Commission's Joint Research Centre relating to the Regulation, specifically focuses on key performance and durability requirements for batteries at cell, module and pack levels. For example, capacity fades, efficiency fades, and power capability over time are related to the state of charge and internal resistance. Battery KPIs such as state of charge, state of health, state of safety, and remaining useful life, are usually calculated without uncertainty provision, by the battery management systems (BMS) in the host (such as electric vehicles, EV). These BMS interpret the measurements of voltage, current and temperature, and do not provide very reliable KPI results, in particular when the batteries are in operation (i.e., being charged or discharged). Unknown accuracy of KPIs and undefined uncertainty can lead to unsafe situations, such as EVs unexpectedly stopping. Therefore, uncertainty evaluation of existing methods and the development of improved methods to determine battery KPIs are needed to provide the metrological underpinning of the new Batteries Regulation and to increase customers' trust in battery products [3, 4].

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The state-of-the-art procedure for KPI determination in BMS is that measurement signals, e.g., voltage, current and temperature, are processed in algorithms based on specific models, created from historical and statistical data in general and specific battery data in particular. These models, however, are not suitable for uncertainty evaluation of KPIs, and existing databases with battery run-time data do not include all the information needed for an uncertainty evaluation. For example, there is a lack of reference setups to perform voltage, current, temperature and electrochemical impedance spectroscopy (EIS) measurements on batteries with representative nominal voltage (i.e., up to 48 V), charging speed (up to 600 A), capacity (up to 150 Ah), and output impedance (down to below 1 mΩ per cell). These need to cover the whole range from battery cells under static conditions to battery modules (with BMS) in operating conditions. New algorithms, models and techniques are needed to calculate the KPIs from these measurements under different operating conditions that facilitate the inclusion of uncertainties of BMS data and propagation of uncertainties through the models. Identification of critical parameters that influence the KPI determination in static conditions and batteries in operation are also required, in order to then develop a metrological framework encompassing the optimum uncertainty evaluation and sensitivity analysis of battery cell and module KPIs.

Previous EC-funded projects have made some advances in this area. For example, project EMPIR 17IND10 LiBforSecUse investigated different measurement techniques to determine the residual capacity of Li-ion battery cells after removal from their first use in EVs, with a focus on impedance-based measurements with an uncertainty of 3 %. The ongoing Horizon Europe project DigiCell explores digitalisation, multi-scale modelling, and AI-driven approaches to improve battery manufacturing and testing. It aims to integrate new measurement tools, interoperable databases, and predictive modelling to enhance the reliability of battery performance assessments. Both of these works need to be extended in the development and validation of new reference systems for KPIs to incorporate uncertainty determination covering both battery cells and modules, contributing to a more reliable evaluation of battery longevity, safety, and reliability.

Objectives

Proposers should address the objectives stated below, which are based on the PRT submissions. Proposers may identify amendments to the objectives or choose to address a subset of them in order to maximise the overall impact, or address budgetary or scientific / technical constraints, but the reasons for this should be clearly stated in the protocol.

The proposal shall focus on metrology research necessary to support regulation for the sustainability and safety of batteries, specifically to develop methods for the traceable assessment of battery cell and module key performance indicators (KPIs), with associated uncertainties, for the reliable determination of battery status during operational life, both under static conditions (i.e. inactive) and in operation (i.e. during charging/discharging).

The specific objectives are

1. To develop traceable measurement setups for the battery module measurement of voltage (V), current (I), temperature (T) and electrochemical impedance spectroscopy (EIS) with nominal voltage up to 48 V, capacity up to 150 Ah, charging/discharging currents up to 600 A, and series impedance down to below 1 mΩ per cell, to support KPI determination of battery modules under static conditions. To determine battery response to conditions mimicking real charging/discharging conditions to support KPI determination during operation. To experimentally determine the influence factors of battery management system (BMS) measurements (i.e., on individual cells) used for KPI determination under static conditions.
2. To develop methodologies and equivalent circuit models for determining KPIs of battery cells under static conditions, and to extend these for determining KPIs of battery modules under static conditions. To identify critical parameters that determine the difference in KPI evaluation between static conditions and batteries in operation and to use the information to extend the developed methodologies, models, and techniques to include in-operation conditions for battery cells and modules.
3. To develop a metrological framework for uncertainty evaluation and sensitivity analysis of battery cell and module KPIs under static conditions and for batteries in operation, targeting uncertainties of around 1 % under static conditions. To evaluate the added value of EIS measurements in addition to existing BMS measurements (V, I, T) in KPI uncertainty determination.

4. To evaluate methodology performance regarding robustness, computational efficiency, and data quality requirements. To investigate the optimal compromise between low uncertainty and fast measurements based on the critical parameters for KPI determination. To expand existing and create new databases with traceable measurements of battery cells and modules, both under static conditions and in operation, with uncertainties and correlations.
5. To support the implementation of Batteries Regulation EU 2023/1542 and facilitate the take up of the technology, methods and measurement infrastructure developed in the project by regulatory authorities, the measurement supply chain, standards developing organisations (IEC, CEN, CENELEC), and end users (such as battery manufacturers and importers).

The proposed research shall respond to documented requirements related to specific regulations and legislation or explore the background and feasibility of expected possible future regulation. To enhance the impact of the research, the involvement of the appropriate user community such as regulatory authorities, conformity assessment bodies, standardisation bodies, and industry, is strongly recommended. Where relevant, proposals are encouraged to build on, or seek collaboration with, existing projects and develop synergies with other relevant European, national or regional initiatives and funding programmes. In particular, links are encouraged with (i) the projects funded under earlier relevant topics of the Horizon Europe programme; or (ii) other relevant European Partnerships.

Proposers should establish the current state of the art and explain how their proposed research goes beyond this. In particular, proposers should outline the achievements of the Horizon Europe project DigiCell and EMPIR projects 17IND10 LiBforSecUse and 16ENG08 MICEV, and how their proposal will build on those.

Proposers should note that the programme funds the activity of researchers to develop the capability, not the required infrastructure and capital equipment, which must be provided from other sources.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 1.0 M€ and has defined an upper limit of 1.3 M€ for this proposal.

EURAMET also expects the EU Contribution to the external funded beneficiaries to not exceed 30 % of the total EU Contribution across all selected projects in this TP.

Any industrial beneficiaries that will receive significant benefit from the results of the proposed project are expected to be beneficiaries without receiving funding or associated partners.

Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the 'end user' community, describing how the project partners will engage with relevant communities during the project to facilitate knowledge transfer and accelerate the uptake of project outputs. Evidence of support from the "end user" community (e.g. letters of support) is also encouraged.

You should detail how your proposal's results are going to:

- Address the SRT objectives and deliver solutions to the documented needs,
- Feed into the development of urgent documentary standards through appropriate standards bodies,
- Facilitate improved industrial capability, or improved quality of life for European citizens in terms of personal health, protection of the environment and the climate, or energy security,
- Transfer knowledge to the transport sector and regulatory authorities.

You should detail other impacts of your proposed JRP as specified in the document "Guide 4: Writing Joint Research Projects (JRPs)"

You should also detail how your approach to realising the objectives will further the aim of the Metrology Partnership to develop a coherent approach at the European level in the field of metrology and include the best available contributions from across the metrology community. Specifically, the opportunities for:

- improvement of the efficiency of use of available resources to better meet metrological needs and to assure the traceability of national standards
- the metrology capacity of EURAMET Member States whose metrology programmes are at an early stage of development to be increased
- organisations other than NMIs and DIs to be involved in the work.

Timescale

The project should be of up to 3 years duration.

Additional information

The links provided in this section are only correct at the time of publication up until the end of the Call year.

The references below were provided by PRT submitters; proposers should therefore establish the relevance of any references.

[1] *Regulation (EU) 2023/1542 of the European Parliament and of the council of 12 July 2023 concerning batteries and waste batteries, amending Directive 2008/98/EC and Regulation (EU) 2019/1020 and repealing Directive 2006/66/EC*

https://op.europa.eu/publication-detail/-/publication/6d4009db-43a6-11ef-865a-01aa75ed71a1

[2] *Performance and durability requirements in the Batteries Regulation. Part 1, General assessment and data basis*

https://op.europa.eu/publication-detail/-/publication/3fcf6f9d-c95b-11ee-95d9-01aa75ed71a1

These references have been provided by EURAMET.

[3] *M/579 - C(2021)8614 COMMISSION IMPLEMENTING DECISION of 7.12.2021 on a standardisation request to the European standardisation organisation as regards performance, safety and sustainability requirements for batteries*

https://ec.europa.eu/growth/tools-databases/enorm/mandate/579_en

[4] *EMN Advanced Manufacturing Strategic Research Agenda*

https://www.euramet.org/research-innovation/metrology-partnership/strategic-research-and-innovation-agendas