Title: Reliable diagnostic methods for enhanced traction batteries

Abstract

Electric vehicles are considered as building blocks for the future worldwide mobility system. The automotive industry needs comparable and traceable reference methods for the assessment of the state of the battery along the whole value chain from production, usage and second life applications. This should be achieved by developing measurement methods and procedures for advancing the evaluation of State of Charge and State of Health of lithium ion batteries by electrochemical impedance spectroscopy and other methods as well as the development of battery models and test protocols.

Keywords

Electro-mobility, lithium ion batteries, battery state parameters, battery lifetime prediction, impedance standard, embedded measurements, battery calorimetry.

Background to the Metrological Challenges

Widespread uptake of electric vehicles is required for meeting Europe's commitment to find sustainable solutions for its transport challenges. Repeatable and reproducible measurement methods for characterising the performance of rechargeable energy storage devices used in electric vehicles are essential to understand and improve this performance. To enhance its competitive position in the global economy European Industry has identified a clear need for improved diagnostic techniques to characterise the performance and lifetime of batteries.

Currently, the limited driving range of electric vehicles is one of the biggest deployment challenges for electro-mobility. A ground-up redesign is needed to fully take advantage of the design freedoms and the opportunities in defining and developing the electric and electronic architecture and components. This should result in increased efficiency and range and make a major contribution towards the transition to fully electric vehicles (FEV's). A particularly important element that needs to be addressed is the battery management system (BMS), which is fundamental for many aspects of electrified vehicle performance, from energy efficiency (and therefore range) to safety, battery life and reliability.

The battery management system (BMS) mainly uses information given by the predictive models of SoC and SoH parameters. These models are difficult to achieve because they depend on a large variety of variables strongly correlated. Recent work [1] has shown the need for including time, temperature and as well as calendar aging in the modelling of battery for improving assessment of SoC. Another recent study [2] has highlighted numeric values of error around 10 % and 7 % to be expected on SoC and SoH respectively, estimated on Li-ion batteries. From the industrial perspective, those values are significant and need to be reduced. Due to the large uncertainty in SoC and SoH determination, batteries are operated in a limited operating voltage window for safety and life-time reasons, which imposes a reduced limit on the driving range of electric vehicles. Impedance spectroscopy in the low- to intermediate frequency range (Hz to kHz) is presently an important tool for SoC and SoH checks, and commercial meters are available. However, the interpretation of impedance spectra is purely phenomenological and measurements at higher frequencies or lower impedance magnitudes are challenging. Moreover, impedance measurement devices are not fully comparable with each other, as no reliable calibration method exists for the whole frequency range. Up to now, traceability through national standards could be provided for EIS measurements performed only on imaginary and real axes. No metrological basis exists for the determination of SoC and SoH.

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 proposal.

The JRP shall focus on the development of metrological capacity and infrastructure that will enable the prediction of the lifetime, performance and improvement of the reliability of lithium ion batteries.

The specific objectives are

1. To provide a metrological basis for the determination of State of Charge (SoC) and State of Health (SoH) for lithium ion batteries. To develop the best laboratory practices for electrochemical impedance spectroscopy (EIS) measurements for evaluation of SoC, SoH etc., including assessment of the influence of the instrumental and procedural variations on the data quality, measurement reproducibility and repeatability. An impedance standard electronic system, applicable in the mHz to kHz and the μΩ impedance range for the purpose of calibration of EIS devices should be developed to address the device dependent results when measuring with different EIS devices.
2. To improve State of Charge (SoC) and State of Health (SoH) determination for lithium ion batteries. Battery performance and lifetime limiting processes should be investigated by standardised life cycle tests, diagnostic tools, linear and non-linear test methods and validated battery models for SoC and SoH. This should involve both time domain and frequency domain techniques at low battery impedances and at load conditions. Exothermic and endothermic heat production rates should be determined quantitatively during storage, charge and discharge. Based on high quality of measured data, considerably improved multi-parameter algorithms for the prediction of the battery behaviour in terms of life-time and performance should be developed.
3. To develop models and test protocols for the characterisation of lithium ion batteries. These protocols and physical-chemical models, associated with uncertainty evaluation, should increase confidence and understanding of the dependency of aging and electrode degradation on the actual operation and working conditions (time, temperature, cell durability, calendar ageing).
4. To engage with industry that manufactures and or / exploits lithium ion batteries to facilitate the take up of the technology and measurement infrastructure developed by the project, to support the development of new, innovative products, thereby enhancing the competitiveness of EU industry.

Proposers shall give priority to work that meets documented industrial needs and include measures to support transfer into industry by cooperation and by standardisation. An active involvement of industrial stakeholders is expected in order to align the project with their needs – both through project steering boards and participation in the research activities.

Proposers should establish the current state of the art, and explain how their proposed project goes beyond this.

EURAMET expects the average EU Contribution for the selected JRPs to be 1.5 M€, and has defined an upper limit of 1.8 M€ for any project.

EURAMET also expects the EU Contribution to the external funded partners to not exceed 30 % of the total EU Contribution to the project. Any deviation from this must be justified.

Any industrial partners that will receive significant benefit from the results of the proposed project are expected to be unfunded 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 JRP results are going to:

- Address the SRT objectives and deliver solutions to the documented needs,
- Drive innovation in industrial production and facilitate new or significantly improved products through exploiting top-level metrological technology,
- Improve the competitiveness of EU industry,
- Feed into the development of urgent documentary standards through appropriate standards bodies,
- Transfer knowledge to the automotive industry.

You should detail other impacts of your proposed JRP as specified in the document “Guide 4: Writing Joint Research Projects”

You should also detail how your approach to realising the objectives will further the aim of EMPIR 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

Time-scale

The project should be of up to 3 years duration.

Additional information

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

[1] K. Smith, J. Neubauer, E. Wood, M. Jun, A. Pesaran, “Models for Battery Reliability and Lifetime Applications in Design and Health Management”, National Renewable Energy Laboratory, NREL/PR-5400-58550.

[2] R. Mingant, J. Bernard, V. Sauvant Moynot, A. Delaille, S. Mailley, J.Hognon, and F. Huet, “EIS Measurements for Determining the SoC and SoH of Li-Ion Batteries”, ECS Trans. 2011 33(39): 41-53.