

Title: Metrology for static and dynamic characterisation of supercapacitors

Abstract

As the performance of supercapacitors (SCs) rapidly improves, they are being used across an increasing number of fields, including as a replacement for batteries in higher-power density applications. SCs are a comparatively new generation of electrochemical energy storage devices where their operating principle and charge storage mechanism is more closely associated with those of rechargeable batteries than electrostatic capacitors. However, the behaviour of SCs differs from both and in order to support the growing use of SCs, accurate characterisation is required for SCs and SCs banks, both in the laboratory and under operating conditions. In addition to this, validated software is needed to identify the equivalent electrical model of SCs for dynamic applications. Quick, traceable and effective measurement techniques are also required to evaluate the State of Charge (SoC) and State of Health (SoH) of SCs and to promote the uptake of SCs in industrial and energy applications.

Keywords

Supercapacitors, Batteries, Energy storage, Measurement, Accuracy, Modelling, Power engineering

Background to the Metrological Challenges

SCs are a comparatively new and rapidly developing generation of electrochemical energy storage devices. In the last three decades, whilst the energy density of batteries has increased by a factor of 3, the energy density of SCs has seen a 20-fold growth. In terms of power density, SCs have increased by a factor of 24, compared to a 25-fold growth for batteries. Unlike batteries, SCs do not require the use of rare metals such as lithium and are also moving towards the use of fully recyclable materials. SCs already have high recyclability, close to fulfilling the 50 % recycling efficiency requirements of the EU's Batteries Directive 2006/66/EC.

Due to their outstanding performance characteristics, SCs are seeing increased use as both stand-alone and complementary energy storage systems and are often a superior choice over batteries in high power density applications, as their typical charging times range from few tens of seconds up to few minutes. The next generation of SCs could also offer a potential alternative electrochemical energy storage technology for aerospace, automotive and energy applications.

Currently, supercapacitor metrics are partially defined by manufacturer guidelines and standards but these lack metrological accuracy. There is also a lack of traceable references for SC banks and a lack of reliable tools to accurately determine the equivalent circuits for SCs/SC banks. To address this, reliable and verified measurement guides with identification software must be developed to allow designers to easily implement SCs into a variety of applications. SCs also require new methods and diagnostic tools to measure SoH and SoC to ensure reliability and allow maintenance to be correctly scheduled, particularly as SC systems have higher average lifespans than batteries and different maintenance needs.

In practical applications, the coexistence of batteries and SCs can lead to complications for charge management systems. Dedicated SC management systems must therefore be developed to ensure reliability and improve performance. The effects of real use on the lifespan and the SoH of SC/SC banks, including the effects of cycles and of waveforms with many harmonics, must also be characterised. Finally, almost all existing studies, standards and guidelines are focussed on carbon-based Electric Double Layer Capacitors (EDLCs), rather than hybrid SCs and pseudo-SCs, which are relatively new devices.

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 JRP shall focus on the traceable measurement and static and dynamic characterisation of SCs.

The specific objectives are

1. To develop metrologically traceable methods, including the assessment of uncertainty, for characterising capacitance, resistance, specific power and energy for SCs of different sizes (from 1 farad up to 1000s of farads, for discharge currents up to 500 A). The developed methods should be suitable for the characterisation of SCs banks with maximum instantaneous discharge power up to 25 kW (e.g., 420 A at 60 V).
2. To develop software/models for identifying relevant parameters for the static and dynamic characterisation of SC and SC bank models. The target error of the developed software/models will be lower than 5 % (for voltages greater than 200 mV). In addition, to define optimised voltage/current waveforms, based on representative SC charging and discharging cycles, for characterising SCs and for validating their measurement.
3. To develop rapid techniques, including the assessment of uncertainty, for accurately measuring the SoC and SoH of SCs. Additionally, to test and verify the developed techniques on at least two different types of SCs.
4. To design and produce a test bench fitted with a measurement system and a measurement procedure to evaluate the actual behaviour of SCs under operating conditions, including battery-SCs hybrid systems. The test bench will also be used for the validation of the outputs of Objectives 1-3 and for the evaluation of at least two applications of SCs in energy systems, (e.g., photovoltaics (PV), uninterrupted power supplies (UPS), electric vehicles (EVs)).
5. To facilitate the take up of the technology and measurement infrastructure developed in the project by the measurement supply chain, standards developing organisations (those associated with the EU's Batteries Directive 2006/66/EC), and end users (e.g., EMN Smart Grids, the aerospace, automotive and energy sectors).

These objectives will require large-scale approaches that are beyond the capabilities of single National Metrology Institutes and Designated Institutes. 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 in this TP to be 1.9 M€ and has defined an upper limit of 2.3 M€ for this project.

EURAMET also expects the EU Contribution to the external funded beneficiaries to not exceed 35 % 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 JRP 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 aerospace, automotive and energy sectors.

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 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.

Time-scale

The project should be of up to 3 years duration.