European Partnership on Metrology
Call 2022 – Digital Transformation, Health, Integrated European Metrology, Normative and Research Potential

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

Title: Metrology support for enhanced energy efficiency in DC transportation systems

Abstract

New feeding architectures are nowadays available to fully recover the braking electric energy in DC transportation systems (railway, metro, light rail, trolleybus). To foster their adoption, and in response to needs expressed by CEN/CLC TC9X and TC14, the project will develop and apply new measurement methods for the determination of the efficiency of the power conversion elements (power converters, power transformers, storage systems) and grid pollution on both AC and DC side. The project will build on EMPIR 16ENG04 MyRailS and will contribute to energy efficiency management strategies, cost-benefit determinations, and instrumentation required in compliance assessments.

Keywords

Power/energy measurement, energy efficiency, DC transportation supply system, unidirectional/bi-directional substations, energy storage systems, energy losses, AC/DC converter.

Background to the Metrological Challenges

In the urban-suburban transportation systems, supplied by unidirectional AC/DC substations, there is a share of the braking electric energy generated by the traction units which is not absorbed directly on-board or by other trains. This share of the braking energy is dissipated by on-board braking rheostat and thus wasted. The experimental data recorded within EMPIR 16ENG04 MyRailS on-board different railway traction-units show a dissipation of the electric braking energy ranging from few percent up to 50 % of the traction energy, amounting to several hundreds of kilowatt-hours for a single journey. The recovery of such an amount of energy considerably reduces the CO_2 emission of the electric transport and improves the quality of the air inside the metro tunnel thanks to the reduction of the environmental overheating produced by the braking rheostats.

The light rail/metro/tram/trolleybus urban-suburban transportation systems are commonly supplied by AC/DC substations of some megawatt connected to the medium voltage (15 kV – 30 kV) AC grid. New high power electronic devices that allow the flow of excess power from DC to AC (reversible substations) or/and stationary storage systems have been proposed and are currently installed. An effective energy efficiency can be reached by combining the infrastructural upgrade, with optimum management of the energy flows, exchanged within the DC system and between it and the upstream AC distribution grid (obj. 1,2,3). The accurate knowledge of the efficiency of the supply system components for the actual operating conditions, is an important information that will allow the management of the electric energy through the new digital-twin paradigm. Moreover, the infrastructure managers need to provide evidence, through reliable figures, of the benefits in terms of energy saving gathered by the investment of European Funding (obj. 4).

The topic of the energy efficiency in the railway system is of increasing relevance. Technical specifications from railway companies relating to procurement of new trains or by the infrastructure managers for the new supply systems were in the past mainly related to the reliability and resilience of the systems, completely neglecting energy efficiency. Nowadays, specifications on energy efficiency are routinely added. Receptivity of new supply systems is one of the new constraints that is important in new tenders. Nevertheless, there is no standard definition of such parameter.

There is a need declared by the CEN/CLC TC9X committee for standardised methodologies for the assessment of the performance of new installations that safeguard the designer, the supplier, the installer and the railway infrastructure manager. The technical report CLC/TR 50646 defines specifications for reversible DC substations and lists a series of key performance indexes that should be proved by the substation provider that are at the moment not yet standardised: i) energy saving (ante, post-opera comparison), ii) harmonic

compensation performance on AC and DC side, iii) reactive power compensation performance, iv) determination of the converter efficiency in traction and regeneration mode (objectives 2, 3 and 4). Another standardisation need, declared by CEN/CLC TC14, is on the investigation on the transformer efficiency. Power transformer losses are presently measured during factory acceptance tests under almost ideal voltage supply conditions. Hence, there is a need to get better insight in the power transformer losses under actual grid and non-linear load conditions, that is, with considerable voltage – current distortions.

The determination of the energy saving provided by the new supply systems requires a holistic approach that involves monitoring both in several points of a section of the metro/tram/railway network and on-board trains. Such a methodology shall be completed by a model that allows the determination of the power/energy flows and the system losses, under real operating conditions. The figures provided by this analysis shall be fostered by standardised methodologies and a rigorous uncertainty determination (objectives 4 and 5).

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 metrology research necessary to support standardisation in determination of performance of DC transportation systems.

The specific objectives are

1. To provide an overview on possible configurations for the non-conventional DC substations (e.g. bidirectional and/or with storage systems) including evaluation of pros and cons for each configuration. To perform a survey on real installations focusing on the design characteristics and the expected or declared energy savings. To establish a suitable measurement approach and to design instrumentation for on-site measurement campaigns.
2. To develop a metrological infrastructure for the calibration of high voltage (3 kV) and high current (1000 A) DC transducers and measurement systems under dynamic conditions with typical timescales from a few hundreds of milliseconds to a few seconds.
3. To develop, calibrate and apply on-site setups and algorithms for the measurement of the energy losses of the unidirectional and bi-directional substations (converters step-up and step-down transformers) and the charge-discharge efficiency of electric storage systems (converter and storage system) with an overall on-site target uncertainty of 10 % in the losses. The setups allow capturing the harmonic/interference pollution on both the AC and DC side up to 20 kHz on the different load and grid conditions, and the analysis of the transient events and low frequency oscillations produced by the functioning of the bi-directional substation.
4. To develop, characterise and determine the accuracy of a method based on the combination of field measurements and models for the determination of the energy saving provided by the upgraded DC supply systems considering the real operating conditions.
5. To contribute to the standards development work of the technical committees CLC TC9X and CLC TC14 to ensure that the outputs of the project are aligned with their needs, communicated quickly to those developing the standards and to those who should use them (e.g. DC transportation system operators, manufacturers, designers), and in a form that can be incorporated into the standards at the earliest opportunity.

The proposed research shall be justified by clear reference to the measurement needs within strategic documents published by the relevant Regulatory body or Standards Developing Organisation or by a letter signed by the convenor of the respective TC/WG. EURAMET encourages proposals that include representatives from industry, regulators and standardisation bodies actively participating in the projects. The proposal must name a “Chief Stakeholder”, not a member of the consortium, but a representative of the user community that will benefit from the proposed work. The “Chief Stakeholder” should write a letter of support explaining how their organisation will make use of the outcomes from the research, be consulted regularly by the consortium during the project to ensure that the planned outcomes are still relevant, and be prepared to report to EURAMET on the benefits they have gained from the project.

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 EMPIR 16ENG04 MyRailS and how their proposal will build on those.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 0.8 M€ and has defined an upper limit of 1.2 M€ for this project.

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 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,
- Transfer knowledge to the transportation sector.

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.

Additional information

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

[1] 003 CLC TC9X Specifications for non-conventional d.c. substation. Performance assessment of non-conventional subs
https://www.metpart.eu/go/need03

[2] 013 CLC TC14 Losses in power transformers under actual grid and non-linear load conditions
https://www.metpart.eu/go/need13