Title: Metrological infrastructure for traceable electrical insulation testing for a reliable electricity grid

Abstract

Transient processes and superimposed high-frequency components have a negative, or even destructive, influence on the existing equipment in DC grids in applications such as the electrical vehicles. The insulating capacity of devices and components need to be tested to address this challenge and meet the Green Deal requirements for a clean and secure energy supply and infrastructure. Proposals should aim to develop measurement techniques, references and calibration capabilities to enable transient high voltage and high current testing.

Keywords

energy efficiency, grid reliability, measurement traceability, very fast transients, impulse voltages, high current and high voltage impulse testing, transient measurement traceability, “green” insulating materials

Background to the Metrological Challenges

Direct current (DC) is an important module for a resource-efficient, carbon-neutral energy distribution. DC grids are generally highly capacitive and fast overcurrent protection devices are required for short-circuit protection. Higher DC voltages are used for electric vehicles. However, electrical faults in the low-inductance vehicle electrical systems, can cause a switching arc with a high pulse rise rate when disconnected, which places a heavy load on the entire on-board electronics. Short circuits and switching represent transient loads with high amplitudes (µs-ms range), which are a key factor for lifetime-reducing stresses of the components. Calibration and testing methods for the impulse currents and voltages are required to ensure the reliability of the current electricity grids through the determination of the grid components and insulating materials lifetime.

In high-voltage testing, the generation and use of steep voltage tests with large amplitudes (up to several 100 kV) and fast impulse rise (times of several hundreds of ns) is already established. The evaluation of impulse voltages is currently dealt within the IEC 60060 series for impulses with rise times longer than 1 µs. Due to the existing frequency components (~1 MHz) this type of evaluation is inadequate. Metrological traceability of the measuring equipment and software for steep voltage tests is urgently needed. In addition to tests with single steep impulse voltages, long-term tests with repetitive voltage pulses are also required to investigate the suitability of insulating materials in power electronics applications with high-frequency electrical stress. In addition, puncture testing of overhead line insulator strings is performed to evaluate withstand strength against fast-rising impulses by measuring the flashover voltage during a fast front impulse. However, different test procedures and circuits are currently used and therefore, there is a strong need for traceable methods and reference measuring systems for puncture testing. On the other hand, high current tests are performed using different current wave shapes like the exponential impulse current, where the current increases from zero to the peak value in a few µs, and thereafter decreases to zero. These impulse current tests should be performed traceably and are mandatory for testing of grid components. Although there are calibration capabilities of European NMIs for time parameters up to 100 µs, the metrological traceability of the measuring equipment is not sufficiently adapted to the needs of testing laboratories. Last, fast-response current shunts are often used to measure high impulse currents. In high voltage and high-power laboratories, shunts are required to provide an undistorted and accurate reproduction of the measurement signal that occurs during short circuit currents. The maximum currents as well as the pulse duration, that can be achieved with such cable generators are too low to be able to calibrate the high-current shunts. Therefore, there is a need for calibration services for step-like currents in the range of several hundred amperes. This could be realised by means of wideband transconductance amplifiers with high output capabilities. Using such new generation capabilities, the need of analysing the amplitude errors, the time parameters, and influences such as skin effect or proximity effects could be met.

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 the traceable measurement and characterisation of electrical insulation.

The specific objectives are

1. To develop validated techniques and algorithms for the evaluation of very fast high voltage impulses for steep voltage testing. To develop reference standards and calibration capabilities at NMIs for the calibration of measuring systems for steep voltages, with an expanded uncertainty of 2 % for peak values. To investigate the influence of steep voltage rise time and high frequency inertia on the insulation material properties (e.g. aging) and to provide recommendations.
2. To develop the metrological tools for device characterisation in puncture testing. To develop traceable measurement systems and calibration services with a target peak uncertainty of less than 2 % and 20 % for rise time. To produce a best practise guide for building calibration and test setups.
3. To develop traceable calibration facilities for impulse current testing using highly energetic impulse currents that comply with IEC 62475 requirements (e.g. 200 kA and 10/350 µs) and target uncertainties for impulse current amplitudes of 1 % and for time parameters of 2 %. In addition, to support the development of a smart specialisation strategy for sharing the developed testing capabilities for current shapes and amplitudes within the European Metrology Institutes.
4. To develop calibration facilities and reference standards for time-domain and frequency characterisation of high current shunts used in short circuit tests that conform with IEC 62475 Annex C requirements (suitable for e.g. switching and protection equipment evaluation). The calibration facilities for current step response measurements developed must cater for:
    a. the current range below 50 A, with rise times in the nanosecond range and short pulse durations and
    b. the current range above 50 A, with rise times in the microsecond range and medium or long pulse durations from hundreds of microseconds to several milliseconds.

    In addition, to incorporate the developed methods into a best practice guide for the determination of high current shunt characteristics (e.g. skin effect, inductance change, resistance change, pre-arcing, arcing, etc.) and the impact of these on measurement uncertainties.
5. To facilitate the take up of the technology and measurement infrastructure developed in the project by the measurement supply chain (e.g. electrical testing laboratories), standards developing organisations (e.g. IEC TC 42), and end users (e.g. electrical components manufacturers, electric vehicles industry, etc.).

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 needs, in particular those supporting the European Green Deal. To enhance the impact of the research, the involvement of the appropriate user community such as industry, standardisation and regulatory bodies is strongly recommended, both prior to and during methodology development.

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

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 2.8 M€ and has defined an upper limit of 2.8 M€ for this proposal.

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 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 electrical testing 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 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] EMN Smart Electricity Grids Strategic Research Agenda
https://www.euramet.org/smart-electricity-grids/strategy/strategic-research-agenda