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

Selected Research Topic number: **SRT-s07**
Version: 1.0

Title: Metrology infrastructure for reliable monitoring of electricity-grid dynamics

Abstract

The rapidly increasing share of Renewable Energy Sources (RES) reduces the ability of an electricity-grid to maintain voltage and frequency stable. Warning signals for upcoming grid instabilities are obtained from tiny changes in the measured frequency, voltage, or power. However, the highly dynamic nature and noisy environment of power networks complicate these measurements and their interpretation. This research focuses on the accurate measurement of electricity-grid warning signals, with a focus on the identification of error mechanisms and improvement of the measurement methods.

Keywords

Electricity grids, grid dynamics, grid stability, data analytics, grid inertia, grid system strength, grid oscillations, warning signals, power system reliability, power system monitoring and control.

Background to the Metrological Challenges

Grid inertia is the ability of the electricity network to respond to the imbalance between electricity supply and demand. As the share of RES increases, inertia is decreasing and the grid frequency becomes unstable, leading to increased faults and blackouts. To prevent these problems, measurement and control of grid inertia is one of the most important issues for grid operators. The increase in RES is also reducing the system strength, or voltage stability, of electricity grids. To mitigate reduced voltage stability, instrument manufacturers are developing innovative equipment for real-time measurement of short-circuit capacity, which is considered the measure of system strength. Furthermore, with increasing RES and electrification of heating and mobility, parts of the grid are overloaded for short periods of time. The resulting increased internal temperature of overhead lines and cables leads to changed impedance which can be determined remotely. However, improved reliability is required to dynamically allow for the thermal ratings to be exceeded, thus reducing the need for reinforcement. Last, with a reduced share of traditional synchronous generation, the controllers in the power converters connecting RES to the grid can interact with each other. Instead of exchanging power with loads, power convertors can exchange power with other RES, leading to sudden and serious low-frequency power oscillations potentially leading to power cuts. Therefore, there is an urgent need for a new actionable metric derived from measurements and their uncertainties, enabling the safe integration of high levels of RES. A metrological infrastructure needs to be established considering the desired metrology landscape with adequate geographical dissemination of services related to the dynamic measurement of grid parameters.

The warning signal to monitor grid inertia is the rate-of-change-of-frequency (RoCoF), which is essentially a small variation of the frequency measured in the presence of the highly disturbed background using phasor measurement units (PMUs). The specification and testing of PMUs is governed by the IEC/IEEE 60255-118-1 standard. As grid operators are looking to deploy new instruments for inertia monitoring, new metrological methods and instrumentation for calibration must be established to verify the reliability of inertia measurements to provide so-called synthetic inertia for frequency stability. Robustness to disturbing influences and fast responsiveness of underlying measurements may be ensured by building on the results of the EMPIR 15NRM05 ROCOF project. Moreover, commercial measurement instruments for short-circuit capacity, reflecting the system strength or voltage stability, are emerging as well, whereas traceability and assessment in the presence of typical grid disturbances are lacking. Capabilities for laboratory and on-site verification must be developed to provide reliable inputs to voltage stability control schemes. In the EMRP ENG52 project an initial algorithm has been developed to determine the impedance, but optimisation and uncertainty analysis in the presence of a highly disturbed background still needs to be performed.

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 characterisation of electricity-grids dynamics and early detection of grid instabilities.

The specific objectives are

1. To provide traceability and validation for upcoming grid inertia measurement methods and instruments measuring the rate-of-change-of-frequency (RoCoF) in the presence of the highly disturbing background of normal grid operation. To develop new approaches to determine RoCoF with at least 100 mHz/s uncertainty in the presence of large background disturbances. To demonstrate the new methods in practice by reliable on-site evaluation of grid inertia and with the use of new reference instrumentation, laboratory testing procedures and calibration services.
2. To provide traceability for “system strength” (short-circuit capacity) and line or cable capacity measurement methods measuring tiny variations in voltage, current or impedance in the presence of the highly dynamic background in normal grid operation. To develop new approaches to determine impedance in the presence of large background disturbances with a target uncertainty less than 1 %. To demonstrate the new methods in practice by reliable on-site evaluation of grid voltage stability and line or cable current capacity and with the use of new reference instrumentation, laboratory testing procedures and calibration services.
3. To investigate and evaluate sub-synchronous power oscillations by developing data science validated methods. To apply these developed methods to grid measurements data sets and identify abnormal system conditions. To develop techniques (e.g. machine learning) for identification of the root cause of grid disturbances.
4. To demonstrate the establishment of an integrated European metrology infrastructure and to facilitate the take up of the technology and measurement infrastructure developed in the project by the measurement supply chain (European Metrology Network on Smart Electricity Grids), standards developing organisations (CENELEC TC8X, IEC TC 8) and end users (distribution and transmission system operators, equipment manufacturers, operators of renewable generation plants).

These objectives will require large-scale approaches that are beyond the capabilities of single National Metrology Institutes and Designated Institutes. To enhance the impact of the research work, the involvement of the larger community of metrology R&D resources both within and outside Europe, plus engagement with existing European research infrastructures and European Partnerships is recommended. A strong industry involvement is expected in order to align the project with their needs and guarantee an efficient knowledge transfer into industry and end users.

Proposers should establish the current state of the art and explain how their proposed project goes beyond this. In particular, proposers should outline the achievements of the EMRP ENG52 Smart Grids 2 and EMPIR 15NRM05 ROCOF projects and how their proposal will build on those.

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 2.6 M€ for this project.

EURAMET also expects the EU Contribution to the external funded beneficiaries to not exceed 25 % 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,

- Develop an integrated self-sustaining European metrology infrastructure,
- Feed into the development of urgent documentary standards through appropriate standards bodies,
- Transfer knowledge to the Electricity Grid and Renewable Energy Sources 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.