

Title: Metrology for reliable power grid data analytics

Abstract

To ensure the safe and reliable operation of the electricity grid with widespread distributed generation, grid operators must have reliable situational awareness in much shorter time scales and based on much larger data sets than with centralized networks. Therefore, grid control has been largely digitized by means of new data-driven algorithms to monitor the dynamic behaviour of the system in real-time. However, there is still a strong need to improve and validate the data collection, modelling, and analysis methodologies. Submitted proposals should respond to this need by developing a framework to test and validate data analysis methods that transform "big data" from field monitoring into actionable information. Furthermore, it should demonstrate a cohesive European metrology effort to support multiple European electricity providers in optimizing the energy grid.

Keywords

Actionable information, artificial intelligence (AI), big data, congestion management, data analytics, data quality, electricity grids, event detection, machine-learning,

Background to the Metrological Challenges

Presently power systems are characterised by a proliferation of renewable and decentralized energy sources. Traditional centralised control approaches are challenged by the increasingly complexity and variability of operating conditions. As such, there is an urgent need for grid operators to enhance their real-time observability capabilities. The advent of digitalisation in grid monitoring equipment offers a promising avenue to address this. By leveraging advanced data-driven algorithms, operators can now gain deeper insights into the dynamic performance of the grid in real-time, thereby enabling more proactive and effective management strategies.

The digitalisation of the energy system is vital in achieving European energy policy targets as stated in the EC's communication on 'Digitalising the energy system - EU action plan'. Aligned with this, digitalisation has been recognized as a major structural trend in power systems by the European Network of Transmission System Operators for Electricity (ENTSO-E). ENTSO-E's 'Research, Demonstration & Innovation Roadmap 2020-2030' lists as a challenge for transmission system operators: "The development of a digital grid ... requires the integration of automation and decision-support tools as well as procedures to manage emerging threats such as cyberattacks." The roadmap further highlights the cyber-physical system as one of three major primary concerns of future power system evolution.

Digitalisation of power systems has tremendous potential to accelerate the clean energy transition, but large-scale integration of advanced data-driven methods into operational decision making is hindered by a lack of trust in their reliability, as confirmed by a global survey of grid operators. Related to this, ENTSO-E has recognised the need for best practice examples as a key to useful implementation of AI-based solutions. According to the European Metrology Network for Mathematics and Statistics "Metrology has a major role to play ... by characterising training data sets ... assessing the robustness of AI models ... ensuring the traceability of the model outputs ... [and] developing a framework for the evaluation of uncertainty."

A requirement for reliable grid data analytics is the availability of fit-for-purpose, high-quality data (Objective 1) as a prerequisite for the accuracy of method and model outputs. At present, existing methods are limited to providing binary indicators and concentrate on specific data streams. By quantifying the reliability of individual measurement data points, it would enable differentiated data selection and the propagation of reliability to final outputs. Furthermore, the proliferation of power electronic devices is decreasing the time span between a

stable state and non-reversible blackout, thus requiring data reliability to be assessed within ever shorter timescales.

The reliability of data analysis methods depends on the input data quality and the availability of representative training and test datasets. Furthermore, if methods are trained only on specific real data, there is a risk of overfitting and loss of generality. A possible solution consists in including benchmark synthetic datasets of possible yet rare scenarios (Objective 2). To this end, a stronger collaboration among grid stakeholders and researchers is needed to avoid the generation of unrealistic scenarios. From this one can expect a great benefit for digital twins and estimation techniques for grid parameters such as impedance at higher frequencies and grid inertia that are still limited by the lack of proper validation tools.

The Strategic Research Agenda of the European Metrology Network on Smart Electricity Grids emphasizes two specific applications of predictive analysis as metrology challenges: detection of abnormal events and congestion forecasting. Advanced data-driven algorithms could make better use of existing grid measurement data to detect abnormal patterns (Objective 3), that can lead to asset damage and grid instabilities. A range of methods have been developed for detection of different grid events, such as power quality disturbances, oscillations, system frequency deviations, and equipment failure. A framework for their reliability assessment is still missing, thus limiting their integration into power system operational decision making. While individual validation approaches exist for specific grid events, there are no unified guidelines on testing and uncertainty quantification, and hence a lack of comparability, transparency, and trustworthiness.

Grid congestion (Objective 4) occurs when network operators reduce power flows to prevent dangerous heating of grid conductors and voltage excursions. As renewable energy sources and electric vehicles are installed, grid congestion is becoming an increasing problem. Traditionally, expected congestion was calculated in day-ahead timescales using generation and demand forecasts. Novel data analysis and AI methods open the possibility of forecasting grid power flows closer to real-time using measurement data from individual grid nodes. These tools can help grid operators optimise the market signals provided to generators and flexible customers, thereby reducing curtailment of renewable energy sources and system balancing costs. The criticality of the decision support from novel data-driven methods for congestion management dictates a thorough evaluation of their reliability and uncertainty through a rigorous testing and validation regime, which is lacking in the state-of-the-art developments.

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 aims to underpin the reliability and trustworthiness of analysis methods that turn data originating from power grid sensor networks into actionable information for grid operators.

The specific objectives are:

1. To quantify the quality of voltage and current measurement data from sensor networks already installed in power grids. Develop and validate methods to identify unreliable measurement data points in real-time, for example, detection of invalid data caused by sensor malfunction. Methods will include comparing grid data to a trained machine-learning profile based on reliable datasets.
2. To develop models and test data sets to complement the use of real data for comprehensive validation and optimisation of grid data analysis methods. Determine the grid model parameters such as impedance and grid inertia from real grid measurement data and implement digital twins of real grids for the simulation of a range of possible grid scenarios and measurement conditions. To use software-based simulation models and laboratory-based grid simulators to generate test data sets for the general testing of grid data analysis methods.
3. To develop a framework to test and validate data analysis methods, including AI techniques, for the early detection of abnormal grid events such as frequency deviations, sub-synchronous oscillations, power quality disturbances, and grid asset faults. Quantify the robustness and reliability of methods using existing grid measurement data as well as the test data sets generated in Objective 2 by determining the uncertainty of the probability of the predicted events.
4. To develop a framework to test and validate data analysis methods, including AI techniques, for forecasting grid congestion and system imbalance between supply and demand, including the use of other data, such as weather predictions and temperature measurements of cables and lines. To quantify the robustness and reliability of methods using existing grid measurement data and the test

data sets generated in Objective 2 by determining the uncertainty of the forecasts. Provide good practice guides on the validation of data-driven grid applications.

5. To facilitate the take up of the technology and measurement infrastructure developed in the project by the measurement supply chain (NMIs, DIs, research laboratories), standards developing organisations (IEEE, IEC/ISO SMART) and end users (grid operators, stakeholders of the European Metrology Network on Smart Electricity Grids).

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, the involvement of the appropriate user community such as industry, standardisation and regulatory bodies, and other European Partnerships 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 1.9 M€ and has defined an upper limit of 2.4 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 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] *COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT: Digitalising the energy system - EU action plan COM(2022) 552*
<https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52022DC0552>
- [2] *ENTSO-E Research, Development & Innovation Roadmap 2020–2030 (entsoe.eu):*
<https://www.entsoe.eu/2020/10/14/entso-e-research-development-innovation-roadmap-2020-2030/>
- [3] *EMN MathMet Strategic Research Agenda*
<https://www.euramet.org/research-innovation/metrology-partnership/strategic-research-and-innovation-agendas>
- [4] *EMN Smart Electricity Grids Strategic Research Agenda*
<https://www.euramet.org/research-innovation/metrology-partnership/strategic-research-and-innovation-agendas>