

Title: Metrology for smart metering in gas networks

Abstract

To meet the goals of the European Green Deal, the replacement of natural gas with renewable alternative gases, e.g., biomethane and hydrogen is essential. The introduction of these renewable gases gives rise to increasing fluctuations in gas flow rates and properties. Current models for operating gas grids, gas allocation and fiscal metering are not equipped to deal with these fluctuations and underrate the measurement uncertainty. Submitted proposals should develop models, reference data sets and fit-for-purpose methods for the safe operating of these gas grids, gas allocation and ensuring that end users pay a fair price for the energy received.

Keywords

Fiscal metering, flow measurement, gas quality, measurement uncertainty, gas allocation, artificial intelligence, machine learning, gas grid safety

Background to the Metrological Challenges

To meet the objectives to mitigate climate change, as articulated in the European Green Deal and the Paris treaty, the renewable energy directive II (RED II) and EU climate legislation aims to establish a carbon-neutral energy supply in Europe by 2050. Furthermore, as published in the REpowerEU plan, there is an urgent need to reduce the dependence on natural gas imports by fast forwarding the clean transition by upscaling biomethane and hydrogen utilisation within the European infrastructure.

The substitution of natural gas with renewable alternatives, such as biomethane and hydrogen is an incremental process and meanwhile a long-term goal in many European countries, such as the United Kingdom, the Netherlands, Germany and France, among others. The European gas industry (e.g., transmission system operators (TSOs) and distribution system operators (DSOs)) are also ramping up their activities to make the transition towards these renewable alternatives. Priorities in this transition include dealing with safety aspects, gas allocation and fair billing. The introduction of biomethane and hydrogen will lead to larger fluctuations in gas grids due to a much more diverse demand and supply, which should be handled carefully to ensure safe operation, ensure that the supply of gas that meets applicable specifications, and to enable fair financial transactions between supplier and buyer, including end-users.

Current practices for fiscal metering assume that measurement results obtained in gas networks are mutually independent. As these measurement results are, in fact, dependent, the evaluation of uncertainty violates internally accepted guidance. Furthermore, the models used do not address the dynamics of gas networks and fit-for-purpose models to deal with, for example, autocorrelation effects in the measurement data are not available. A first evaluation of the magnitude of these effects indicates an underrating of the measurement uncertainty by some 35 %. Knowing measurement uncertainty is key to assessing and managing risks with regard to safety and supply specifications in gas grids.

Quantification of totalised quantity due to dynamic flow changes was studied as part of the 19ENV09 MetroPEMS project. It was found that traceable quantification of potential errors due to flow rate changes during a measurement batch is a challenging topic. There are, however, no publicly available studies on quantifying error from flow rate changes for fiscal metering, where turbine, rotary, Coriolis or ultrasonic flow meters are typically used. A framework for totalisation has been developed by the 21GRD05 Met4H2 project which developed methods for evaluating autocorrelation in gas metering data could be integrated into.

Artificial intelligence (AI) and machine learning (ML) are being probed and introduced in gas grids to improve their operation, ensure safety and potentially also for gas allocation and billing. Current practices for fiscal metering presume transparency of the measurement models employed and ignore any prior knowledge. When using AI and ML, prior knowledge (“training data”) is a key feature of such models, and there is an unanswered question of whether AI/ML-based systems can provide measurement results with the required traceability. If so, the conditions for using these systems in the frameworks of gas allocation and fiscal metering must also be determined. The use of AI/ML in measurement also seems to have friction with generally accepted principles of demonstrating competence in measurement. The proposed work addresses several objectives in the EMN Mathmet roadmap for AI/ML [1]. The perceived untrustworthiness of AI/ML outputs is one of these and this issue is also one of the key issues in the EU act on AI.

Measurement data of gas networks are generally not publicly available, as these data are considered to be commercially sensitive. Nevertheless, such data are key for modelling the dynamics in gas grids and developing fit-for-purpose type A methods of evaluating measurement uncertainty but need to meet the key requirements of Findability, Accessibility, Interoperability, and Reusability (FAIR). A further practical issue with such data are gaps in the information about the context, e.g., the calibration status and performance of the measurement instrumentation. Furthermore, for developing such models, flow metering data from flow meter calibration facilities would be extremely helpful, as such data set a baseline for the behaviour of metering data in gas grids and the conditions of measurement are much better known. Applicable requirements prevent the reuse of such data for research purposes, and furthermore these calibration data are not necessarily to scale for understanding, for example, serial correlation effects.

For modelling gas grid data, the validation of methods for data evaluation and the evaluation of measurement uncertainty, synthetic data sets that realistically mimic real-world phenomena in gas grids, with known features (e.g., correlated measurement errors, serial correlation in the indications), are also required. With such data sets, methods (including AI/ML-based methods) can be assessed for performance and benchmarked. These datasets should also be FAIR, detailing how they were created and what context was taken into account.

The methods for evaluating gas allocation and fiscal metering data require urgently improvement, and the corresponding standards (e.g., ISO 15112 and OIML R140) should be extended to provide realistic values for the measurement uncertainty, including for time averages (e.g., hourly, daily averages), so that measurement results are metrologically traceable and coherent. Underrated uncertainties are detrimental to this coherence and cause that risks cannot be properly calculated, let alone be mitigated. With an increasing number of suppliers and customers, and a greater diversity in gases, this is a rapidly increasing issue in the safe operation of gas grids and in billing.

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 development of metrology capability in smart metering for gas networks.

The specific objectives are

1. To create datasets for time-resolved gas flow measurements, including temperature, pressure and gas composition using state-of-the-art methods and techniques, mimicking changes in gas grid flow rate, pressure, temperature and gas composition typically seen in real world scenarios in order to enable studying and modelling of autocorrelation effects. These reference data sets should be made FAIR and published with their full context (meta data).
2. To develop methods for the evaluation of autocorrelation in gas metering data, as well as uncertainty evaluation for time averages of gas quantity and calorific value, and link these with models used to operate gas grids. The methods should be applicable to grids for hydrogen, natural gas and hydrogen-enriched natural gas (enriched to the most common level), and fully validated. Synthetic data sets should be created with known features (e.g., correlated measurement errors) for validating data processing methods used in the operation of gas grids, including fiscal metering.
3. To test the possibility of integrating artificial intelligence and machine learning in smart metering and monitoring systems used in gas grids with respect to its applicability to produce measurement results that meet the requirements of OIML R140 and ISO 15112, and the Guide to the expression of Uncertainty in Measurement.

4. Using results from Objectives 1-3 and liaising with industry to get feedback on applicability, to develop and validate an integrated package of methods for the evaluation of measurement data to support gas allocation and the fiscal metering of the most commonly used blends of natural gas with renewable gases (e.g., hydrogen and biomethane) as well as renewable hydrogen.
5. To facilitate the take up of the technology and measurement infrastructure developed in the project by the measurement supply chain (GERG and MARCOGAZ), standards developing organisations (ISO/TC 193, ISO/TC 197, CEN/TC 234, EURAMET TC-F and TC-MC), legal metrology organisations (WELMEC, OIML) and end users (e.g., gas network operators).

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. In particular, proposers should outline the achievements of the EMPIR project 19ENV09 MetroPems and Metrology Partnership project 21GRD05 Met4H2 and how their proposal will build on those.

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 3.5 M€ for this proposal.

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 gas network operators and the gas monitoring 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.

These references have been provided by EURAMET.

[1] *EMN Mathmet Strategic Research Agenda*

<https://www.euramet.org/research-innovation/metrology-partnership/strategic-research-and-innovation-agendas>

[2] *EMN Energy Gases Strategic Research Agenda*

<https://www.euramet.org/research-innovation/metrology-partnership/strategic-research-and-innovation-agendas>