TITLE: Metrology for Smart Gas Distribution Grids

Abstract

Gas grids are an essential part of the energy supply of Europe. Increasingly, the sources of gas are diversified with the grids fed by different gas qualities, a trend that will increase as new biogas sources are added to the network. In order to facilitate efficient control of the growing grids, to realise energy savings and to ensure accurate accounting, a new metrological and reliable approach to real-time determination of the amount of energy and other relevant quantities of the gas transmitted through and extracted from the grid is needed.

Joint Research Projects (JRPs) submitted for this topic should aim to develop new procedures and tools underpinning advanced network reconstruction and simulation techniques to enable the determination of all relevant feeding, transportation, extraction and energy parameters of the gas for any branch of the grid at any time with defined uncertainty acceptable to the industry and consumer.

Conformity with the Work programme

This Call for JRPs conforms to the EMRP 2008 [1], section on "*Grand Challenges"* related to *Energy* on pages 8 and 23.

Keywords

Smart Gas Grid, Gas Network Reconstruction, Energy Content, Thermo-physical Properties, Safe and Secure Data Transmission, Distribution Grid, Distributed Systems, Model-Based State Estimation, Bayesian Estimators.

Background to the Metrological Challenges

Natural gas and in the future, gas from renewable sources, play a crucial role in Europe's energy supply, both in industry and in households. 24.8 % of the primary energy consumption is provided by natural gas. At the end of 2008 the total number of gas customers connected to the EU27 natural gas grid was 112 503 900 customers [1], serving approximately 210 million individual consumers. The pipeline length of the EU25 natural gas grid (in 2005) amounted to 139 984 km for transmission and 1 189 265 km for distribution [2].

In January 2007 the European Commission adopted a communication [5] proposing an energy policy for Europe, with the goal to combat climate change and boost the EU's energy security and competitiveness. Natural gas and biogas play an important role in this scenario, because their use causes intrinsically less pollution than other fossil fuels.

Gas from different sources has different and even changing composition, and hence calorific value. The physical properties of the gas also vary, impacting on the calorific value. With the liberalisation of the gas market in Europe, the gas qualities fed into the network will become increasingly diverse. In case of (natural or bio) gas transportation and distribution the grids are currently under-instrumented for the future requirements with regard to the measurement of gas composition and properties. There is a clear need for the development of capability to generate metrological and reliable quantitative information suitable for legal and contractual use, grid control and prediction of spatial distribution in the network, based on a combination of advanced modelling and measurements in under-instrumented grids. Many, especially large gas companies, already use network state simulation software for dispatching purposes. With a set of comprehensive boundary conditions these state simulations can be used to calculate the calorific value and other gas quantities and, thus, the energy content of a gas portion when it is travelling through the grid to the customer. These boundary conditions, encompassing a very large number of precise measurements in the grid at many locations, are required to provide sufficient reliability to enable the calculated values to be used for billing purposes under legal control. When the required boundary conditions cannot be met completely the state simulation is not conclusive and cannot reliably be applied for contractual and legal purposes in distribution grids.

However, in recent years, progress has been made which is applicable in the case of under-instrumented networks. This development is due to progress in the theory and practice of numerically solving differential equations and in control theory. In particular the improved understanding of probabilistic differential equations achieved in recent years and the development of model-based Bayesian state-estimators for dynamic and distributed measuring systems promise to facilitate further progress in gas-grid reconstruction and simulation. Additionally, these techniques and tools will allow for processing uncertain and incomplete input information as well as providing the knowledge about relevant energy and transportation quantities (output quantities) by their *degree of belief* and uncertainties, respectively, as quality parameters. The latter is an indispensable prerequisite for establishing both metrological traceability and legal reliability. With the future introduction of smart gas meters in the households, state reconstruction might even be possible at the household level.

The improvement of both network control and energy measurement/accounting is related directly to the savings that producers and users can earn from better knowledge of the state and distribution of energy and other relevant quantities in the grid and their particular extraction respectively. Along with better knowledge of the energy delivery and consumption costs, this allows for significant savings in production and distribution as well as on the consumption side.

Scientific and technological objectives:

Proposers should aim to address all of the stated objectives. However where this is not feasible (i.e. due to budgetary or scientific / technical constraints) this should be clearly stated in the JRP protocol.

The objectives are based around the PRT submissions. As experts in the field, JRP proposers should establish the current state of the art, which may lead to amendments to the objectives - these should be justified in the JRP proposal.

This topic aims to develop new procedures and tools underpinning advanced network reconstruction and simulation techniques to enable the determination of all relevant feeding, transportation, extraction and energy parameters of the gas for any branch of the grid at any time with defined uncertainty. Specific objectives are:

- Modelling of the spatial and temporal distribution of energy and other relevant quantities in the grid, enabling to quantify the relevant gas properties at any (transition or extraction) point of the grid at any time, and to optimize the grid design

- Identification of the most relevant parameters for optimization of the grid design, such as the number and location of measuring instrumentation.
- Development of necessary measurement procedures with reduced uncertainty for calorific value, gas flow, state variables, composition of fuel as input to the gas network reconstruction and simulation systems

Potential impact

Proposals must demonstrate adequate and appropriate participation/links to the "end user" community. This may be through the inclusion of unfunded JRP partners or collaborators, or by including links to industrial/policy advisory committees, standards committees or other bodies. Evidence of support from the "end user" community (eg letters of support) is encouraged.

Where a European Directive is referenced in the proposal, the relevant paragraphs of the Directive identifying the need for the project should be quoted and referenced. It is not sufficient to quote the entire Directive per se as the rationale for the metrology need. Proposals must also clearly link the identified need in the Directive with the expected outputs from the project.

You should also detail the impacts of your proposed JRP as detailed in the document "Guidance for writing a JRP".

You should detail how your JRP results are going to:

- Feed into the development of documentary standards and guidelines through CEN, or other standards developing bodies or other appropriate bodies
- Interact with the gas companies and gas distribution sector to identify requirements and needs
- Transfer knowledge and tools to the gas companies and the gas distribution sector to enhance their up-take of this new technology

Additional information

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

[1] "Natural Gas Consumption in EU 27, Turkey and Switzerland in 2008", Eurogas, Brussels, 12 March 2009, http://www.eurogas.org/uploaded/08P141%20-%20Press%20release%20on%20Evolution%20of%20Gas%20Consumption%202007.pdf

[2] "Statistics 2005", Eurogas, Brussels, 01.01.2005, http://www.eurogas.org/uploaded/statistics%202005.pdf

[3] "Natural gas demand and supply. Long term outlook to 2030", Eurogas, Brussels, 16.11.2007, http://www.eurogas.org/uploaded/Eurogas%20long%20term%20outlook%20to%202030%20-%20final.pdf

[4] "Eurostat statistical books. Gas and electricity market statistics, 2007 edition", Luxembourg: Office for Official Publications of the European Communities, 2007, http://www.eds-destatis.de/downloads/publ/en8_gasandelectricprices.pdf

[5] "Communication from the Commission to the European Council and the European Parliament: An energy policy for Europe". Commission of the European Communities, Brussels, 10.01.2007, http://ec.europa.eu/energy/energy_policy/doc/01_energy_policy_for_europe_en.pdf