TITLE: Metrology for Smart Electrical Grids

Abstract

The electricity grid is the backbone of our modern society. The increase of decentralised energy supply forces the network to become a 'smart grid', facilitating greater competition between providers, enabling greater use of renewable energy sources, and providing market forces with the tools to drive energy conservation. However, they are highly complex, difficult to optimise and vulnerable to instability. Understanding and improving the observability and controllability of Smart Grids within an uncertainty framework is essential to their development

Joint Research Projects (JRPs) submitted for this topic should develop a metrological infrastructure to support successful implementation of a Smart Grid in Europe [1]. The research addresses a series of metrological challenges that will provide essential support to ensure low losses, security of electricity supply and grid stability, low loss long distance transport of electrical energy, and fair trade between commercial parties employing the grid.

Conformity with the Work Programme

This Call for JRPs conforms to the EMRP 2008 [2], section on "*Grand Challenges"* related to *Energy* on pages 8 and 23.

Keywords

Distributed generation, electricity, electricity transport, energy losses, grid stability, network metrology, power quality, renewable energy, renewables, revenue metering, security of supply, sensor networks, smart grid, smart meters.

Background to the Metrological Challenges

The EU has pledged to reduce carbon emissions by 20 % by 2020. To achieve this target a huge number of smaller renewable sources of electricity (e.g. solar-voltaic panels, wave power and wind turbines – both domestic and commercial) will be generating supply, and feeding into the grid. Renewable sources are by their nature intermittent, they are geographically diverse, and thus they behave quite differently to large power plants. The incorporation of many decentralised electricity sources into the grid can cause deterioration of the power quality, and degradation of the grid's supply. The interactions between the many sources, and the multiple loads that draw power from the grid are highly complex and take place over an intricate network of distribution links. Together these have a high risk to the stability of the grid, with the potential to:

- degrade the power quality of the supply from the grid,
- cause higher losses in the grid
- cause catastrophic failure of the grid
- possibly cause malfunctioning of equipment connected to the grid

Power outages and blackouts have a profound social and economic consequence to modern society [12], and therefore any instability in the grid must be identified as soon as possible so that remedial action can be taken to avoid grid failure.

The challenge ahead is the creation of a ‘Smart Grid’ for Europe, with two way energy flows, connecting large and small, centralised and dispersed power sources. The Smart Grid is essential to the successful uptake of renewable electricity generation, to support a low carbon future. However it needs substantially more measurements related to power quality and network stability to ensure the quality and reliability of the electricity supply, because the current metrological infrastructure cannot ensure reliable traceable measurements needed for a complex grid.

A further challenge is the monitoring of the smart grid to ensure that the revenue metering of such a complex two way supply can be fairly accurately monitored and fairly billed. There is potential for:

- insecurity of the electricity supply because it is hard to monitor, and
- unfair trade between parties trading electrical energy to and from the grid

In order to achieve **Grid Stability** the grid must first be accurately and reliably monitored, indeed actual measurements in the grid are a key issue for SmartGrid R&D [3]. One emerging method is to use Phasor Measurement Units (PMUs), however such measurements have been found to be unreliable, in one test [12], readings differed by as much as 47 microseconds – or a difference of 1 degree at 60 Hz. This lack of consistency and traceability of PMU results has significantly hampered wide uptake of PMUs in global European grid stability monitoring systems therefore improved metrology of PMUs is essential and urgent. Wide Area Measurement Systems (WAMS) based on PMU data will provide the input parameters to grid stability models for day-to-day monitoring of grid stability. The PMU is, in fact, considered to be one of the most important future measuring devices in the electricity grid, given its capability to provide synchronized phasor measurements of voltages and currents from widely dispersed locations in the grid.

Poor **Power Quality** leads to extra losses and malfunctioning of equipment connected to the grid and ultimately may even lead to grid failure. A recent study [4] estimated that the costs of bad power quality in Europe costs around 150 B€ per year. Therefore maintaining acceptable power quality whilst encouraging the integration renewable energy generators is essential. Currently power quality (PQ) measurements are rarely performed in the grid, but this will become increasingly important, as well as the need for (on-site) calibration of such set-ups.

Complex waveform metrology, currently under development in the iMERA-Plus JRP on “Power and Energy” has a role to play in **smart metering**. By analysing the electronic signature of electrical appliances, it should be possible to identify the power used by each appliance. Itemising domestic electricity bills will give consumers the information they require to make choices about the appliances they use, as well as showing them the benefits of making energy savings. A 3-year study in Italy involving 30 million homes has shown that such real-time metering information has reduced electricity consumption by about 5 % per year. Itemizing the appliances could lead to even greater savings. Such demand balancing and control will become pan-European in light of the required supergrid that will be used to transfer power internationally from energy rich countries with wind, wave and solar resources to the central EU population zones. This leads to a pan-European research drive to ensure interoperability across international borders.

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.

The following objectives shall be covered in order to underpin the establishment of a *smart* electrical grid which enables the greater use of decentralized, renewable energy sources and stimulates competition between energy suppliers:

- Develop the measurement framework for monitoring stability of smart grids including the use of PMUs
- Develop traceable on-site energy measurement systems in electrical grids for ensuring fair energy trade"
- Develop tools for portable and remote measurement of power quality and efficiency
- Develop metrology for existing and planned smart meters for the analysis of electronic signature of electrical appliances for efficient power flow management in grids
- Develop sensors and metrology including dynamic modelling and uncertainty analysis techniques necessary for determining the system state for stabilised power flow.
- Enable European standards development (this is in impact)

Your JRP should detail how it will partner with electricity utilities, network operators, telecommunication companies and academic groups, in order to gain access to the configuration details of the networks, the emerging Smart Grid strategies and experimental micro grids required for validation.

Any proposed JRP should indicate how the proposed JRP differs or complements from the currently funded iMERA-Plus JRP on "Power and Energy" T4.J01. Details of this project can be found here: http://projects.npl.co.uk/power_energy

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.

In your JRP submission please detail the impact that your proposed JRP will have on the following Directives of the European Commission:

- Directive 2003/87/EC [5]
- Directive 2004/101/EC [6]
- Directive 2008/101/EC [7]

You should also detail other 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 urgent standards
- Transfer knowledge to and from electricity utilities, network operators, telecommunication companies and academic groups
- Support to new regulation (metering codes) for revenue metering in smart grids

Any proposed JRP should clearly detail how it will build on the results of the currently funded iMERA-Plus JRP on "Power and Energy".

Additional Information

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

[1] European Technology Platform Smart Grids – Vision and Strategy for Europe's Electricity Networks of the Future", European Commission EUR 22040, 2006, available online http://ec.europa.eu/research/energy/pdf/smartgrids_en.pdf

[2] European Metrology Research Programme. Outline 2008 Edition - November 2008, http://www.euramet.org/index.php?eID=tx_nawsecuredl&u=0&file=fileadmin/docs/EMRP-outline2008.pdf&t=1248796946&hash=9da9ceb781370f04c322ac48068deca5

[3] "Strategic Research Agenda For Europe's Electricity Networks Of The Future" http://www.smartgrids.eu/documents/sra/sra_finalversion.pdf

[4] R. Targosz and J. Manson, "Pan European LPQI Power Quality Survey", CIRED 2007 conference. See http://www.leonardo-energy.org/webfm_send/165 and http://www.leonardo-energy.org/european-power-quality-survey-results

[5] Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC (Text with EEA relevance) – amended 2009 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:2003L0087:20090625:EN:PDF

[6] Directive 2004/101/EC of the European Parliament and of the Council of 27 October 2004 amending Directive 2003/87/EC establishing a scheme for greenhouse gas emission allowance trading within the Community, in respect of the Kyoto Protocol's project mechanisms (Text with EEA relevance) http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32004L0101:EN:NOT

[7] Directive 2008/101/EC of the European Parliament and of the Council of 19 November 2008 amending Directive 2003/87/EC so as to include aviation activities in the scheme for greenhouse gas emission allowance trading within the Community (Text with EEA relevance) http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32008L0101:EN:NOT

[8] SEC(2008) 85/3 COMMISSION STAFF WORKING DOCUMENT. IMPACT ASSESSMENT Document accompanying the “Package of Implementation measures for the EU's objectives on climate change and renewable energy for 2020” 23 Jan 2008. http://ec.europa.eu/energy/climate_actions/doc/2008_res_ia_en.pdf

[9] Desertec website (www.desertec.org) An example of a European super-grid based on HVDC, linking the optimal locations of different renewable energy sources.

[10] EU Supergrid http://en.wikipedia.org/wiki/European_super_grid

[11] US Power outage “grid cascade failures” 2003

[12] A. P. Meliopoulos, Vahid Madani, Damir Novosel, George Cokkinides et al. (2007-10), "Synchrophasor Measurement Accuracy Characterization". North American SynchroPhasor Initiative Performance & Standards Task Team (Consortium for Electric Reliability Technology Solutions) http://www.naspi.org/resources/pstt/ir_naspi_synchro_measure_accur_charc_20070826.doc