Publishable JRP Summary Report for SmartGrid II Measurement Tools for Smart Grid Stability and Supply Quality Management

Background

The increased use of renewable energy is vital to meet emission reduction targets and ensure security of supply in Europe. However, renewables are intermittent and unless the energy flows are measured and controlled, the increased use of these distributed generation resources will cause costly power quality degradation, ultimately leading to wide-spread blackouts. Smart grids are the mechanism to reliably utilize large amounts of renewable energy and new measurement tools as proposed in this project are essential for their stable operation.

The emergence of GPS synchronized measurements has opened up many new measurement opportunities to determine grid parameters and behaviour over a wide geographical area. This is a common-theme to the techniques that will be developed in this project which will ultimately lead to new grid management methods to help design, control and stabilize Smart Grids of the future.

Need for the project

Smart Grids are primarily required to dynamically balance variable renewable supply with variable demand to achieve grid stability and prevent a degradation of power quality (PQ) that would otherwise lead to cascading failures and power blackouts.

Network operators need tools to measure the quality and stability of the electricity supply under the challenging dynamic conditions prevalent in networks with a high penetration of distributed renewable generation. Wide-area measurement systems using phasor measurement units (PMU) are increasingly seen as the “life-support monitors” for Smart Grids and they present many new opportunities to understand the complex dynamics of these networks. However, unless properly formulated and deployed, these new measurement techniques have many potential pitfalls that will give rise to misleading results that could ultimately undermine, rather than boost confidence in future-networks.

This JRP will engage with this rapidly developing technology and implement a complete metrology framework for PMUs. In particular, addressing the exacting calibration requirements for PMUs and associated transducers when used to monitor the stability of distribution networks where very small phase changes are critical. Furthermore, new synchronized grid measurement techniques are needed to determine the propagation of PQ in networks, locate significant sources of PQ disturbance and measure network impedance, all of which are essential to Smart Grid planning and management.

Scientific and technical objectives

The common theme to the measurements to be developed in this JRP is the use of multiple digitizing instruments placed at geographically remote locations around an electricity grid. These instruments are time-synchronized to form a wide-area measurement system using GPS. Specifically the JRP has the following objectives:

- ***PQ Propagation***. Determination of PQ propagation mechanisms associated with a selection of disturbance sources in a variety of distribution and transmission networks. The results will be

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reconciled against network topology, drawing conclusions to support future network planning and standardization.

- ***PQ Disturbance and Fault Location***. Amplitude and phase measurements for multiple GPS synchronized instruments will be used to determine power flows associated with major PQ disturbance / faults and their locations will be estimated.
- ***Network impedance and system resonances.*** Wide-area measurements and the analysis of system impedance and resonances in HV/MV/LV networks. Results will be evaluated against network design data and models.
- ***PMUs in Distribution Networks***. Selection, comparison and validation of new PMU algorithms suitable for use in LV and MV distribution networks. These networks are characterised by smaller distances and hence require higher phase sensitivity whilst at the same time accounting for a higher level of PQ disturbances.
- ***Dynamic calibration of PMUs***. Develop extensions to a laboratory PMU calibrator to provide new calibration support for the dynamic performance of PMUs.
- ***On-Site Calibration of PMUs.*** Undertake on-site measurements using reference PMUs, suitably modified to calibrate/verify the operation under realistic conditions including PQ disturbances.
- ***PMU/PQ Transducer Characterization***. Develop/apply wideband evaluation facilities for transducers and optimize non-invasive transducers specifically applied to the PMU/PQ measurement chain.
- ***Digitized Waveform Corrections***. Develop and evaluate signal processing methods to apply transducer frequency response corrections to sampled complex wave shapes typically present in PMU/PQ measurements. Reconcile the propagation of transducer uncertainties through complex PQ and PMU algorithms.

Expected results and potential impact

Utilizing wide-area measurement technology, this JRP proposes significant advances in Smart Grid measurements in the following areas:

- *Power Quality (PQ) Propagation Measurements*: PMU based tools will be developed to measure and locate significant or aggregated PQ disturbances as they propagate the wider grid network.
- *A Metrology Framework for Phasor Measurement Units (PMU):* develop and validate new PMU algorithms that are suitable for LV and MV distribution networks. Develop new measurement and calibration methods for the dynamic performance of PMUs.
- *Network impedance measurements:* develop and apply PMU based methods to measure the network impedance at the fundamental and harmonic frequencies on sections of HV/MV grid.
- *A Transducer Measurement Framework in Support of PMUs/PQ:* provide a measurement and uncertainty framework for the medium/high voltage level current and voltage transducers used in PMU and PQ measurement systems

Through these activities, this JRP will deliver verified and practical measurement tools for the planning and management of smart grids with the aim of ensuring **reliable, stable, high-quality energy-supply** from renewable-based generation. The outcomes will benefit stakeholder groups including designers of smart grids systems, electricity network operators, manufacturers of instrumentation and government policy-makers/regulators.

PMUs are emerging as the life-support monitors of future electricity networks, they will detect the on-set of grid instability though the detection of very-small phase changes. These instabilities ultimately lead to local or even national power failure with often **catastrophic economic and social consequence**. The advent of large-scale renewable-generation makes such events considerably more likely, and will especially affect the LV and MV distributed Smart Grids.

Network-wide PQ is directly linked to network stability which can be managed by network operators if reliable and actionable measurement data is available. The measurements tools proposed in this JRP are essential

to network planners to determine the effect of additional renewables of the grid and to decide whether or not expensive network reinforcement is required in order to maintain a sufficient PQ level.

Knowledge will be disseminated to the stakeholder community primarily through their active participation in on-site measurement campaigns. Involvement of network engineers in the measurements and analysis of the results will develop a shared ownership of the project outputs creating an inside track to the implementation and take-up within the industry. To-date, over 30 Stakeholders have engaged with the JRP.
Standardization is essential to ensure that network-critical PMU and PQ measurements can be made reliably with instrumentation from any manufacturer. As these measurements involve particularly complex parameters and are subject many unpredictable influences, the JRP will provide input to future standards to define hardware, algorithms, immunity to disturbances and test conditions.

JRP start date and duration:	June 2014, 3 years.
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