Smart Transmission Grids
Operation and Control

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Timeline and Project Partners

October 2011 – December 2015

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Smart Transmission Grids
Operation and Control

Objectives

- to support the development of better *tools for operation and control* of power grids
- to create innovative *applications* that will enable a more reliable operation and control of the Nordic power grid and with better information about security margin
- to increase Nordic collaboration through *common research platform* and software interfaces (software and hardware) for application prototyping and testing
Research approach

Evolution of networks **passive → active**

- faster and larger changes in operation
- need of advanced and smarter tools to manage the increasing complexity of the grid
- new solutions in ICT and power engineering together will enable more flexible, secure and sustainable energy systems
- main involved aspect is the network monitoring by means of **Phasor Measurement Units** (PMUs)

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PMU definition (as stated in IEEE Std.C37.118-2011):
“A device that produces synchronized measurements of phasor (i.e., its amplitude and phase), frequency, ROCOF (Rate of Change of Frequency) from voltage and/or current signals based on a common time source that typically is the one provided by the Global Positioning System UTC-GPS.”
**Research Platform:**
Low voltage PMU Network

- PMUs are connected on the LV networks in our laboratories

**PMU typical configuration:**

- GPS antenna
- Pulse-Per-Second
- GPS receiver
- A/D conv.
- Phasor Measurement Unit
- Synchrophasors, Frequency, ROCOF
- Modem
- Data streaming

**Diagram:**

- On-line PDC
- Installed PMU
- On-line PMU
Research Platform: Real-time PMU Data Exchange

- Each partner (PMUs, PDC) exchanges an "Output Stream" with each other partner.
- PDCs installed locally allow data archiving and real-time access for all partners.

[Diagram of PMU network setup]
Research facilities, PMU TestLab at IPE

PMU ABB RES-521, IEEE C37.118
PMU NI cRIO-9074

Frequency Disturbance Recorder - FDR-GI-GSY

The University of Tennessee

Software:
Edition PDC: Intel Server System R1000RP
Software: SEL-5073 SYNCHROWAVE

APC UPS

Graph showing data over time.
Application developments

STRONg²rid «apps»

- **Angle stability**
  - PMU-based oscillation damping using reconfigurable controllers (KTH)
  - Centralised LQR and MPC control for damping inter-area modes (Aalto)

- **Voltage stability**
  - Real-time voltage stability monitoring using Lyapunov exponents (KTH)
  - Online voltage stability monitoring based on PMUs and system topology (NTNU)

- **State estimation**
  - Transmission line temperature and sag estimation using PMU measurements (IPE)
  - Power oscillation damping using load control (KTH / Landsnet)

- **Protection & Emergency cntrl**
  - Identifying cascading outages (DTU)

- **ICT**
  - ICT solutions for new generation WAMS and WACS (KTH)
  - Damping estimation using LS (Aalto)

PMU Test and Applications for Small Signal Stability Assessments (DTU)
**IPE research topics and results**

- The objective of IPE task was to apply PMU in transmission line temperature, sag and clearance parameter estimation.

- An algorithm for sag and clearance calculation in overhead power lines was proposed and tested in real-time conditions with a focus on thermodynamics and line mechanics behaviours.

- This research will contribute to real-time operation performance. An exact line sag and clearance calculation will increase potential total transfer capacity (TTC).
Test in real-time conditions

• On 11.08.2015, an experiment was conducted during two hours in collaboration with Latvian TSO, on line No. 301 Valmiera – Tartu between pylons No. 1123 – 1124. The temperature and sag were measured using
  ▪ clearance to ground measurement unit
  ▪ weather station
  ▪ thermovision camera
• Temperature estimation methods in dynamics have similar answers, with low variations.
• Sag and clearance fluctuations have less than ~ 1cm difference in 15 minutes.
A large number of PMU-assisted WAMPAC applications have been developed within the STRONg²rid project. All these applications have been tested using Real-Time Hardware-in-the-loop (RT-HIL) facility at SmarTS-Lab.
Apps developed in collaboration with KTH

Monitoring & Visualization

Mobile Apps

Inter-Area Oscillation Assessment

Forced Oscillation Detection

Short-Term Voltage Stability Assessment

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Apps developed in collaboration with NTNU
Collaboration

Collaboration with Partner Universities

A. 8 Educational Courses (2 on SmarTS-Lab, 2 on Labview Modules and 4 from International Faculty)

B. Several joint publications

SmarTS-Lab Training Program (Sept 23-October 04, 2013)

Power System Dynamics and Control (Professor Taranto) 22-26 April 2013

TuT-KTH collaboration (PMU compliance Testing)

3-day course on renewable energy integration, 2014
Concluding remarks

• Increased awareness at the TSOs about the possibilities of utilizing PMU technology in operation and control
  – TSOs are starting deployment and pilot installations

• New competences have been gained at the universities, institutes and at the TSOs through research, PhD education, educational courses and dissemination activities

• STRONG motivation to continue the R&D collaboration at the Nordic/Baltic level

Major challenges while developing WAMPAC applications were mainly technical:
• communication latency
• loss of data / bad data
• GPS vulnerability (Jamming/Spoofing Attack)
• measurement noise due to hardware PMUs
• signal scaling which affects overall SNR
Key aspects

• For policymakers, there are technologies and methods available or under development that provide totally new system information and control possibilities. This can radically enhance power system operation and the possibility of coping with a changing and less predictable system based on Renewable energy sources.

• There is a need for more research to further develop the methods, as well as to initiate more pilot projects to demonstrate the new solutions in a full-scale environment.

• Increased efforts are required to adopt standards for PMUs, which depends on the strengthening of technical aspects of interoperability of standards for real-time data exchange and of software application systems.
Thank you for your attention!