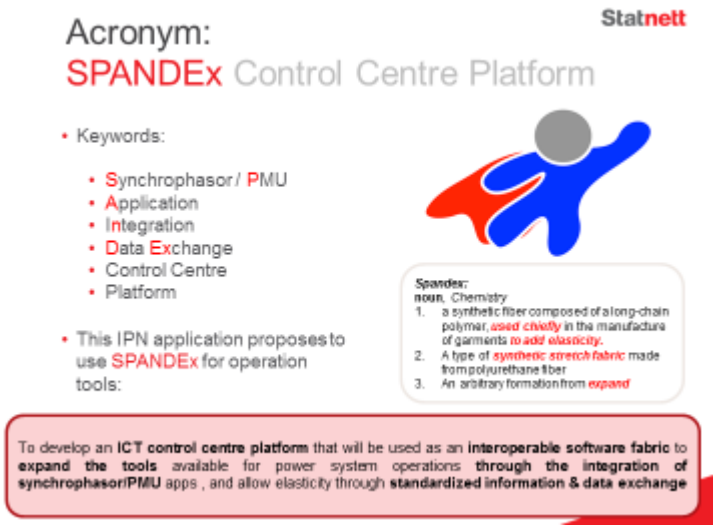
“Synchrophasor” projects: **STRONgrid** and **SPANDEx**

Kjetil Uhlen

Statnett pilot project



Nordic R&D collaboration

Norwegian University of Science and Technology

Outline

- Short about STRONgrid (Nordic R&D collaboration)
- Short about the plan for SPANDEx (control centre platform)
- Pilot demonstrations → possible applications
- Thoughts about future plans and possibilities

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Smart Transmission Grids Operation and Control

Kjetil Uhlen

October 22, 2015

STRONgrid
Smart Transmission Grids Operation and Control
KTH - NTNU - AALTO - DTU - UI - TUT - FEI

STRONgrid

NTNU – Trondheim
Norwegian University of Science and Technology

Outline

- Project objectives, drivers, ambitions and overview
- Nordic collaboration through common research platform
- Overview on application developments

Smart Transmission Grids Operation and Control

A project funded by

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– *And co-funded by Nordic TSOs and DSOs*

- **Objectives**:
  - Support the development of better ***tools for operation and control*** of power grids
  - Create innovative ***applications*** that will enable more reliable operation and control of the Nordic power grid
  - Identify ***technology gaps*** and limitations that need to be addressed in the future ***as an input to roadmaps*** for smart grid and integration of renewable energies.

Project partners

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Academia

Industry

NTNU

KTH VETENSKAP OCH KONST

LUND UNIVERSITY

Aalto University
School of Science and Technology

DTU

UNIVERSITY OF ICELAND

Institute of Physical Energetics

TTÜ 1918

Statnett

SVENSKA KRAFTNÄT

TROMS KRAFT

gothia power

FINGRID

LANDSNET

STRONgrid

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Motivation: More extremes!

- Trends:
  - Faster and larger changes in operation
  - More variability and uncertainty
  - Less predictability → ***Less time to take decisions***
- Operators need new tools!
  - More real-time information, higher resolution and synchronised measurements
  - Need for more automatic control
- New technology is available
  - New possibilities..

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Project goals

- Create innovative *applications* that will enable operation and control of the Nordic power grid more reliably and with better information about security margins.
  - ➢ **Emphasis on PMU/WAMS as an enabler of Smart Grids**

- Develop a *research platform* comprised by power systems emulators (software and hardware labs), PMUs, PDCs and specialized software.
  - – **Create a "Nordic University Cluster"**

- Develop a set of *software interfaces* allowing PMU-data application development, and implementation.

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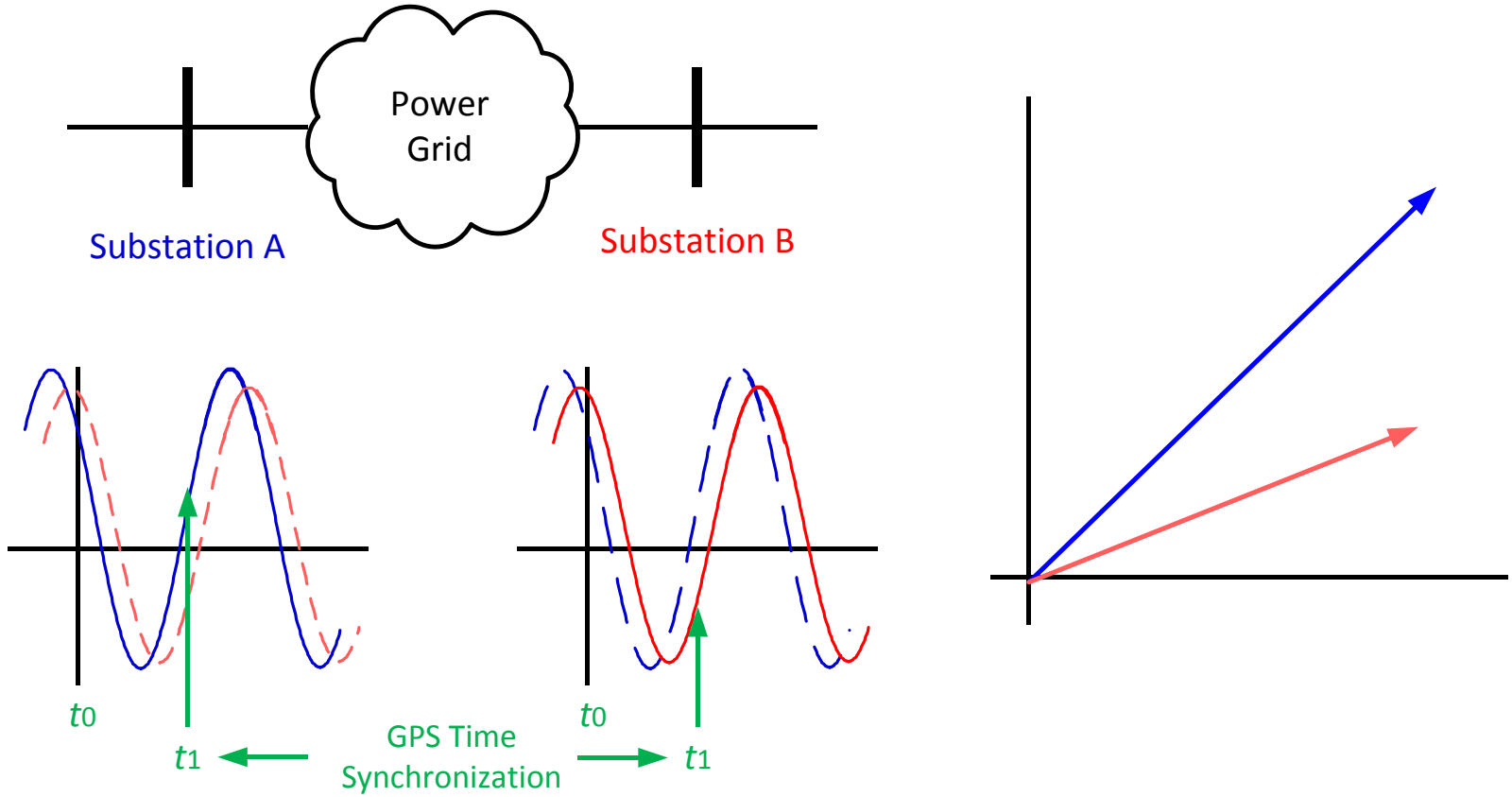
Synchronized Phasor Measurements



By synchronizing the sampling processes for different signals – which may be hundred of miles apart, it is possible to put their phasors on the same phasor diagram.

Source: Phadke

Research Platform: Low voltage PMU Network

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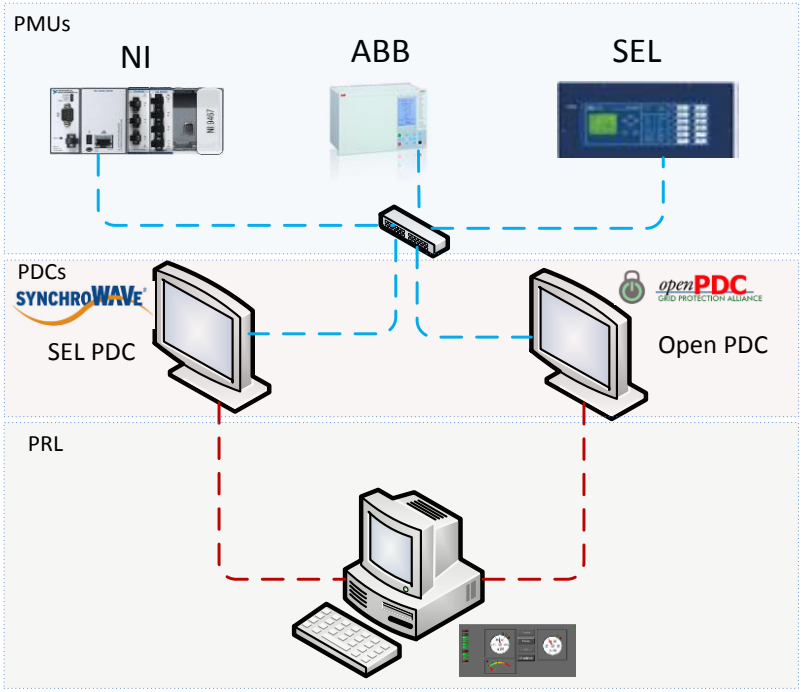
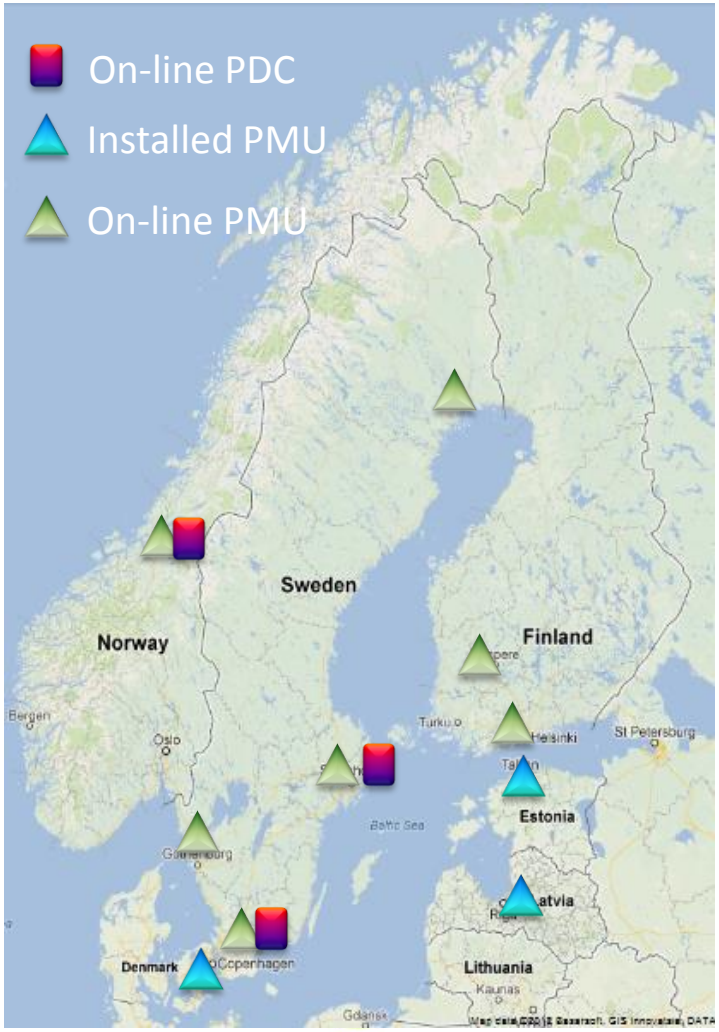
- PMUs are connected at the LV networks in our laboratories





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Research platform:

Distributed P2P Data Sharing for real-time PMU Data Exchange

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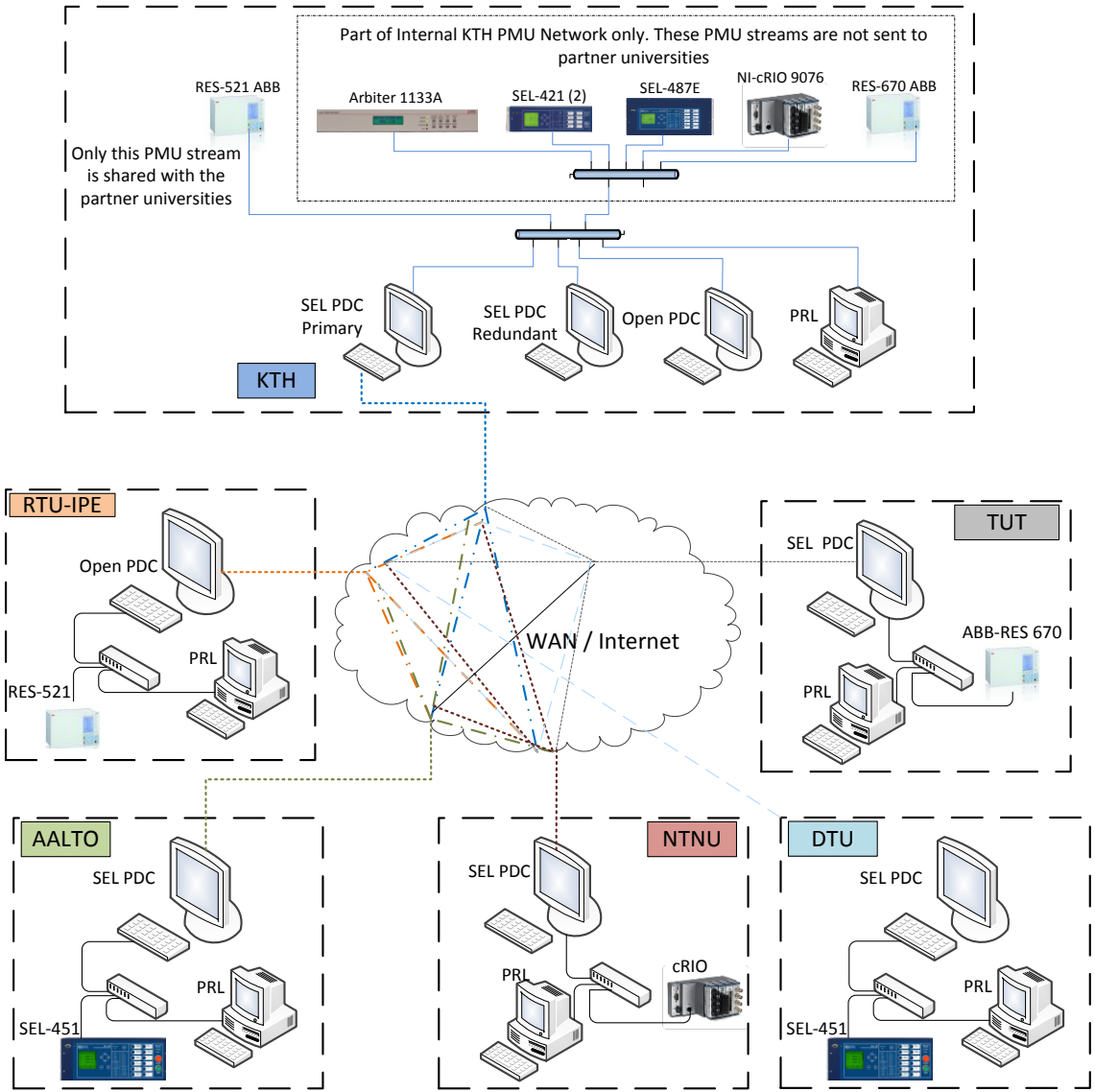
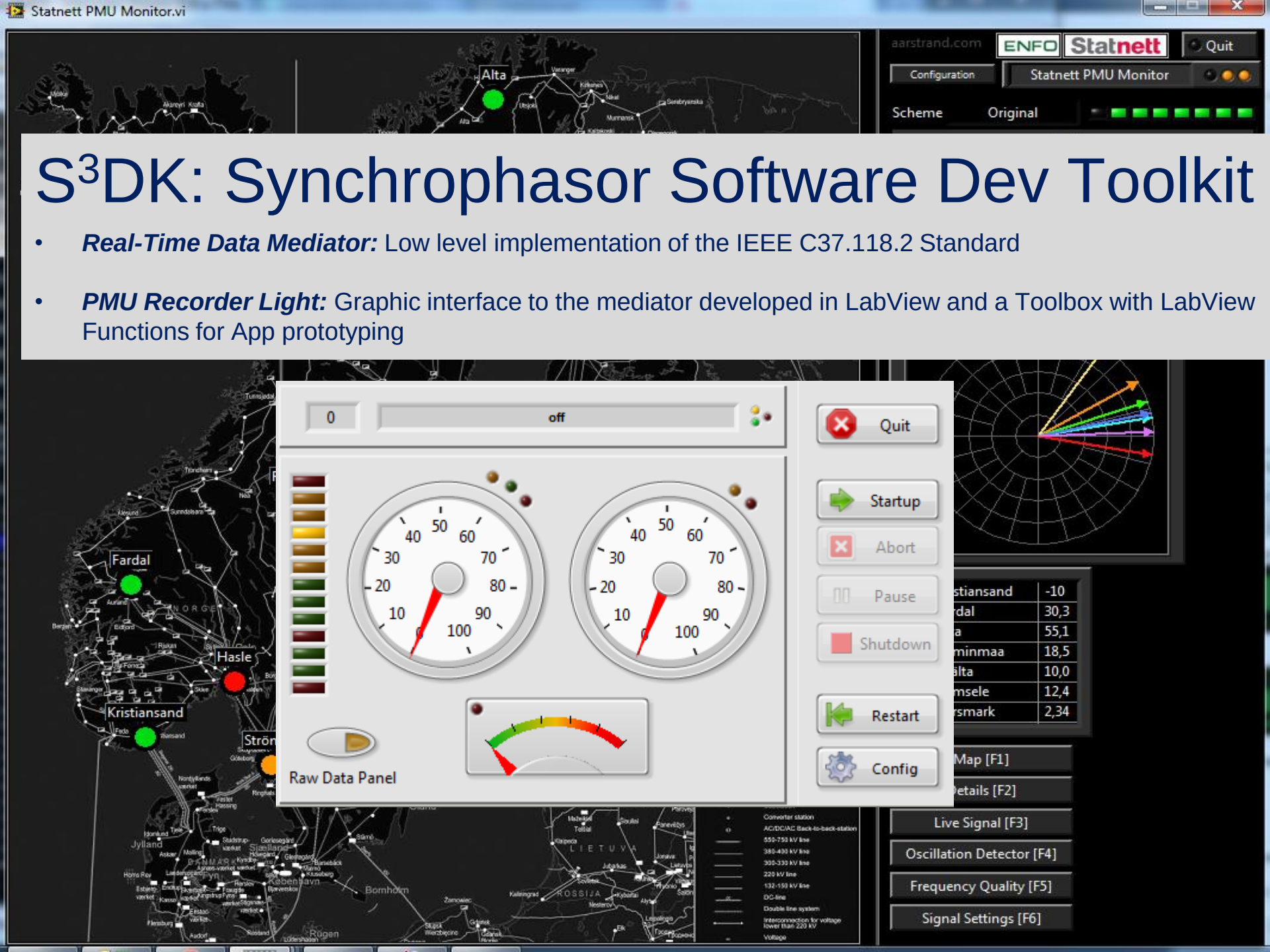
- Each University (PMUs, PDC) exchanges an Output Stream" with each other university.
- PDCs installed locally allow data archiving and real-time access for all partners.
- Avoids SuperPDC, thus eliminates a single point of failure



Test-bench:

New WAMPAC software applications Development and Testing


Statnett PMU Monitor.vi
aarstrand.com
ENFO
Statnett
Quit
Configuration
Statnett PMU Monitor
Scheme
Original
Alta
S³DK: Synchrophasor Software Dev Toolkit
• Real-Time Data Mediator: Low level implementation of the IEEE C37.118.2 Standard
• PMU Recorder Light: Graphic interface to the mediator developed in LabView and a Toolbox with LabView Functions for App prototyping
0
off
Quit
Startup
Abort
Pause
Shutdown
Restart
Config
Raw Data Panel
Fardal
Hasle
Kristiansand
Map [F1]
Details [F2]
Live Signal [F3]
Oscillation Detector [F4]
Frequency Quality [F5]
Signal Settings [F6]

Sample Application
WAMS Visualization Tool - Mobile

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- Portable Monitoring Applications

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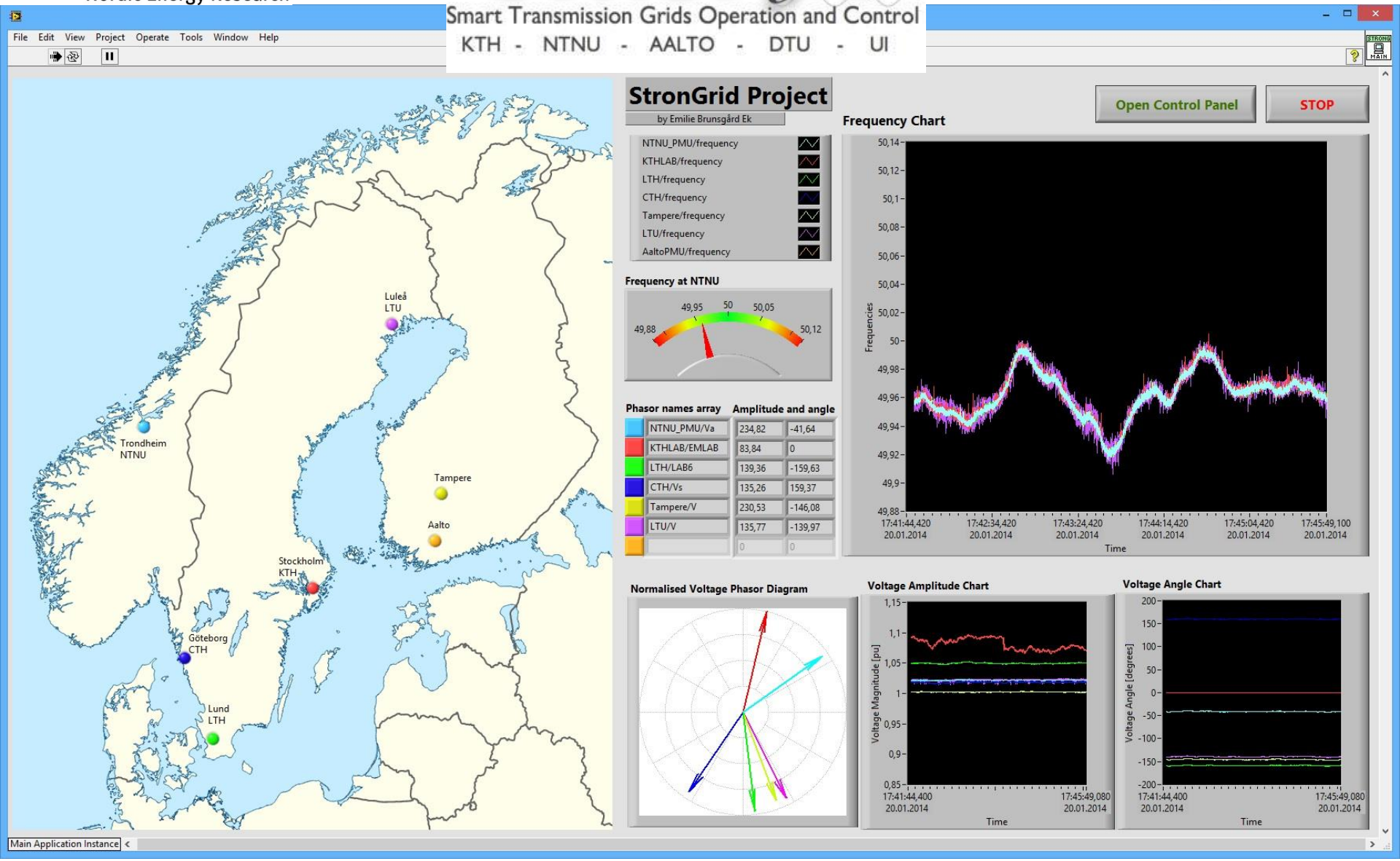

STRONg²rid «apps»

earch

Angle stability

- PMU-based Oscillation damping using reconfigurable controllers (Almas, Rebello, KTH)
- Centralised LQR and MPC control for damping inter-area modes (Mäki, Aalto)
- PMU Test and Applications for Small Signal Stability Assessments , (Ghiga, DTU)
- Power oscillation damping using load control, (Gudrun, KTH / Landsnet)

Voltage stability

- Real-time voltage stability monitoring using Lyapunov exponents (Lavenius, KTH)
- Online voltage stability monitoring based on PMUs and system topology (Dinh Thuc Duong, NTNU)

State estimation

- Estimation of Transmission line temperature, sag and losses by using PMU measurements (IPE / TUT)
- Damping estimation using LS (Tomi Kalmi, Aalto)
- Modal identification methods, MAR, SOBI, NExT-ERA, Bayesian (Seppänen, Turunen, Aalto)
- Spectral identification to support modal identification (Turunen, Seppänen, Aalto)
- Statistical analysis and prediction of oscillation damping (Sulla, Seppänen, Koivisto, Turunen, Lund, Aalto)

Protection & Emergency cntrl

- Identifying cascading outages (Petersen, DTU)

ICT

- ICT solutions for new generation WAMS and WACS, (Wu, KTH)

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Concluding remarks

- A “Nordic University Cluster” has been established
- New competence have been gained at the Universities and at the TSOs through research, PhD education, courses and dissemination activities
- Increased awareness at the TSOs about the possibilities of utilizing PMU technology in operation and control.
  - **TSOs are starting deployment and pilot installations**
- STRONG motivation to continue the R&D collaboration at the Nordic/Baltic level

SPANDEx

Projcet overview
Kjetil Uhlen

NTNU 2016-05-25

Statnett

Background: Context

- Statnett has made considerable efforts with PMU since 2000's
  - Focus on collecting data
  - In-house display and data collection SW prototypes
  - Developed applications with universities
- Natural next step→ Pathway for utilization: prove what is useful in operation?
  - Need for integration/interfacing with EMS / SCADA
  - Need for benefit assessment

- **SPANDEx** IPN project → pilot
  - Develop new applications and interface with applications existing in the EMS / SCADA systems
  - Applications for use both in Regional and National Control Centres
  - Gain experience, identifying possibilities and value/benefits of PMU/WAMS in operation
  - Focus on also building knowledge regarding ICT infrastructure, Big Data and Cyber Security

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Acronym:
SPANDEx Control Centre Platform

- Keywords:
  - Synchrophasor / PMU
  - Application
  - Integration
  - Data Exchange
  - Control Centre
  - Platform
- This IPN application proposes to use SPANDEx for operation tools:

Spandex:
noun, *Chemistry*

1. a synthetic fiber composed of a long-chain polymer, ***used chiefly*** in the manufacture of garments ***to add elasticity.***
2. A type of ***synthetic stretch fabric*** made from polyurethane fiber
3. An arbitrary formation from ***expand***

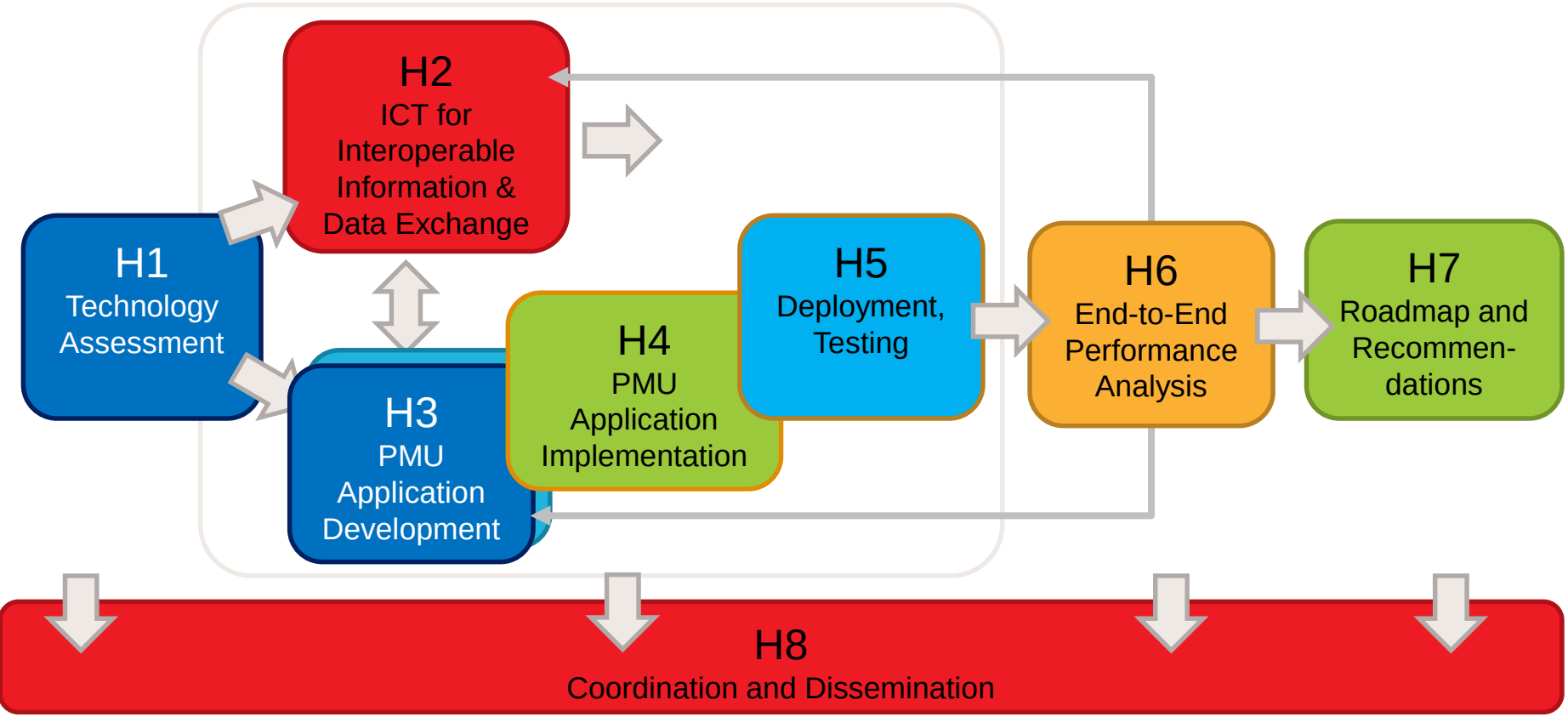
To develop an **ICT control centre platform** that will be used as an **interoperable software fabric** to **expand the tools** available for power system operations **through the integration of synchrophasor/PMU** apps , and allow elasticity through **standardized information & data exchange**

Statnett

SPANDEx - Objectives

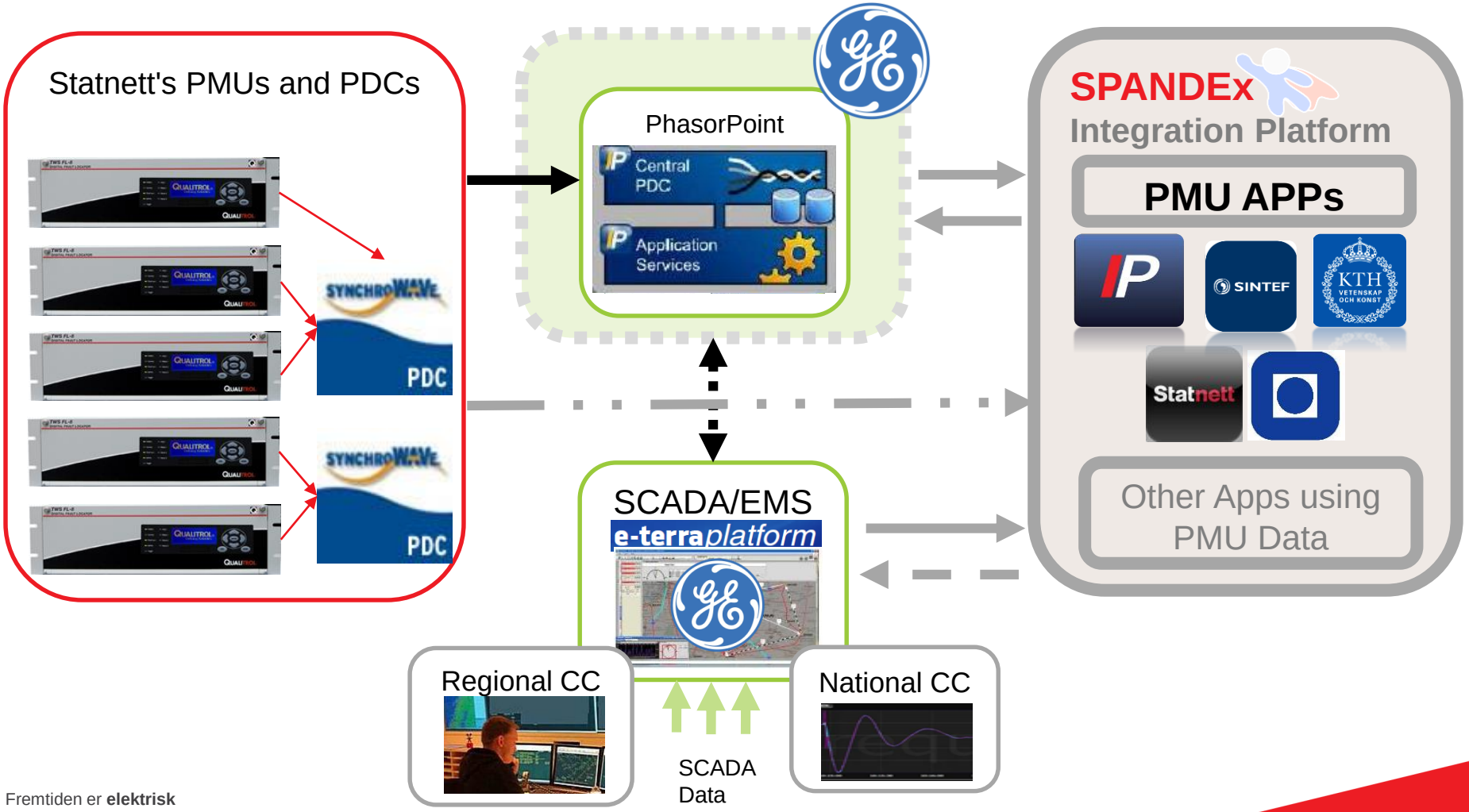
- Development and adaptation of new control room applications for power system monitoring based on synchronised phasor measurements
- Implementation and integration/interfacing of selected functions in the control room environment
- Gain knowledge on ICT requirement and data management issues related to massive use of Phasor measurements.
- To gain new experience and knowledge through testing and performance analysis.
- Development of a road map for full integration of the technology in the operating processes.

Project Structure



Recap:

Project concept: The proposed conceptual system architecture as a starting point for more detailed planning, development and implementation of software applications and data interfaces.



Benefits of Synchrophasor Technology, by Application[1]

	Increased System Reliability	Increased Asset Utilization and Power System Efficiency	Increased Organizational Efficiency
Real Time			
Wide area visualization	✓		✓
Frequency stability monitoring and trending	✓		
Voltage monitoring and trending	✓		
Oscillation detection	✓		
Phase angle monitoring and trending	✓	✓	
Resource integration		✓	
Adaptive islanding and black-start capability	✓		
Event detection	✓		✓
Adaptive relaying	✓		
Power system stabilizer/oscillation damper	✓		
Automated protection	✓		
State estimation	✓		
Off-Line			
Post-event analysis	✓		✓
Model validation	✓	✓	✓

[1] Adapted from the Advancement of Synchrophasor Technology in Projects Funded by the American Recovery and Reinvestment Act of 2009, U.S. Department of Energy, Electricity Delivery and Energy Reliability.

SPANDEx – Possible Applications

- Voltage collapse indicator
  - *Areas of interest*:
    - Stavanger area
    - Hammerfest / Melkeøya
    - Lofoten/Vesterålen area
  - ..possibly combined with demand response / load shedding schemes in Northern Norway
- Power oscillation monitoring
  - *Areas of interest*:
    - Northern Norway – North Finland
    - Southern Norway – Interarea modes

SPANDEx – Possible Applications

- Islanding detection and monitoring
  - *Area of interest:* Indre Sogn
  - Objective: Fast alert and stability monitoring in islanded part (frequency and voltage)
    - .. Possibly later combined with adaptive load shedding or other control actions, such as governor adjustments

- System protection schemes (SPS)
  - *Application of interest*: Existing and new SPS schemes, e.g. Generation Shedding Scheme for increased capacity on Hasle corridor
  - *Objective*: Improve situational awareness to improve operation of SPS – "take actions sooner and better but only when needed".
  - Minimize costs and avoid potential cascading failures.

- Monitoring Frequency bias and Inertia
  - *Area of interest*: Southern Norway
  - Selected power plants

Future possibilities

- *Research and Development:* Continue (Nordic, European, ..) collaboration to develop applications
- *Demonstration:* More pilot projects to gain experiences in operation
- *How?*
  - Fully utilize our labs.
  - Maintain and improve the “Nordic Wide Area Platform”
  - Make software platforms and interfaces that enable easy implementation and testing