

Research on Wide area control and system protection at NTNU

Kjetil Uhlen, 26 May 2021



NTNU

Outline

- Previous experience
 - Utilization of synchrophasor information for WAMS → 2010
 - Wide area power oscillation damping (WACS) 2011
- (WAMS application research and developments) 2012-2019
- Ongoing research
 - WACS: Adaptive WAPOD using online system identification 2019 →
 - WAPS: System protection with wide area information

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Wide area measurements for *POD Control*

- PMUs streaming phasors from:
 - Nedre Røssåga
 - Kristiansand
- SVC Located at Hasle
 - PDC receiving voltage phasors
 - Extracts voltage phasor angle
 - ABB Mach2 Controller
 - Local control
 - WAPOD Control
 - Switch-over logic



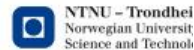
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“The future control centre” ..tidligere FoU-aktiviteter



STRONGrid



Nordic R&D collaboration

Statnett pilot project

Acronym: **SPANDEX** Control Centre Platform Statnett

• Keywords:

- Synchrophasor / PMU
- Application
- Integration
- Data Exchange
- Control Centre
- Platform

- This IPN application proposes to use **SPANDEX** for operation tools:



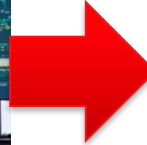
Spandex:

1. **Chemistry noun.** a synthetic fiber composed of a long-chain polymer, **used extensively** 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

Controlling the grid:

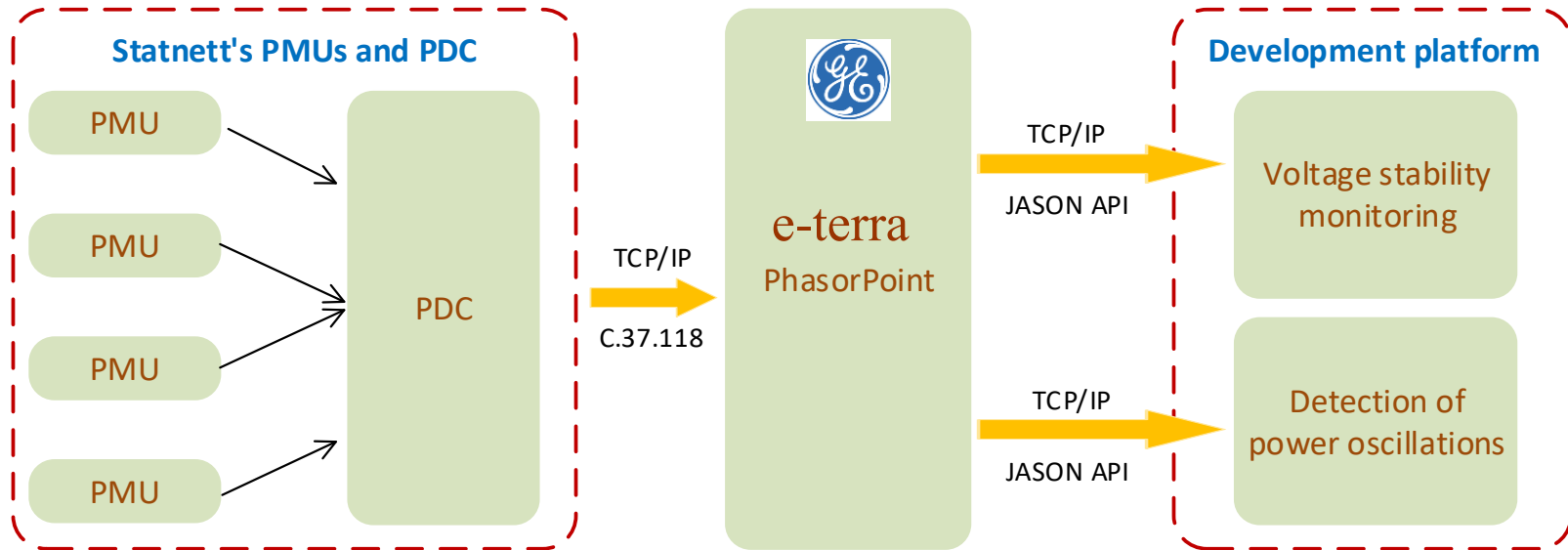
Increased complexity requires better information and more automation!



- We need:
 - «full» awareness of the process
 - "full» control of the process
- In all states...
- From normal operation to extreme disturbances
- At all times....

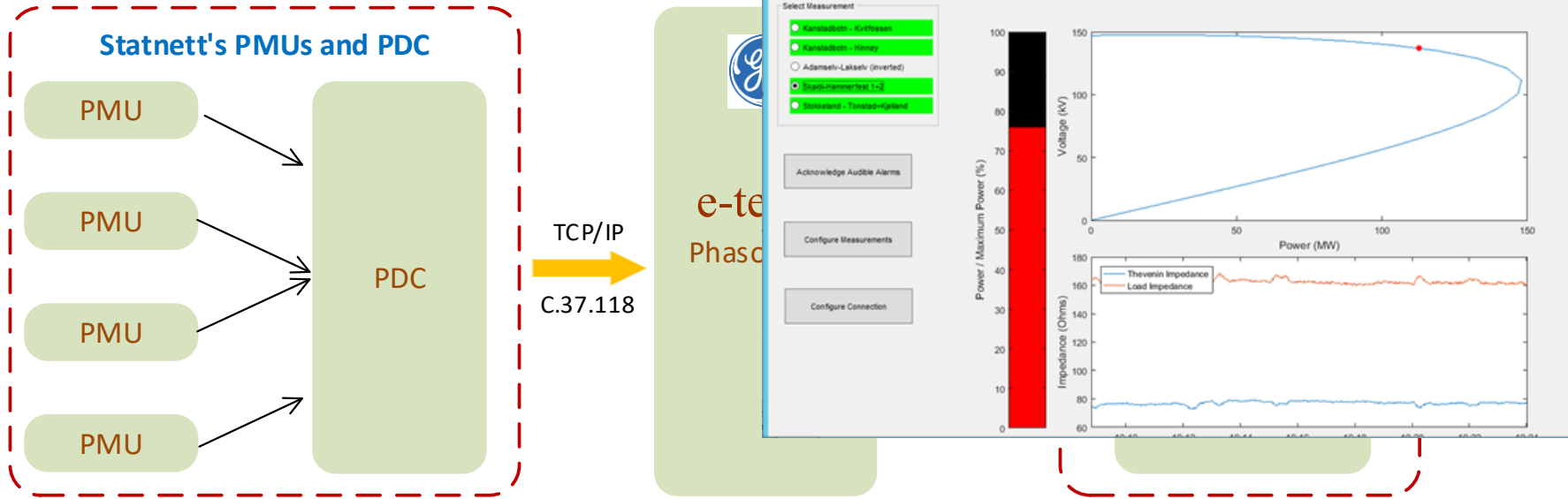
Spandex

Development platform for new control room applications



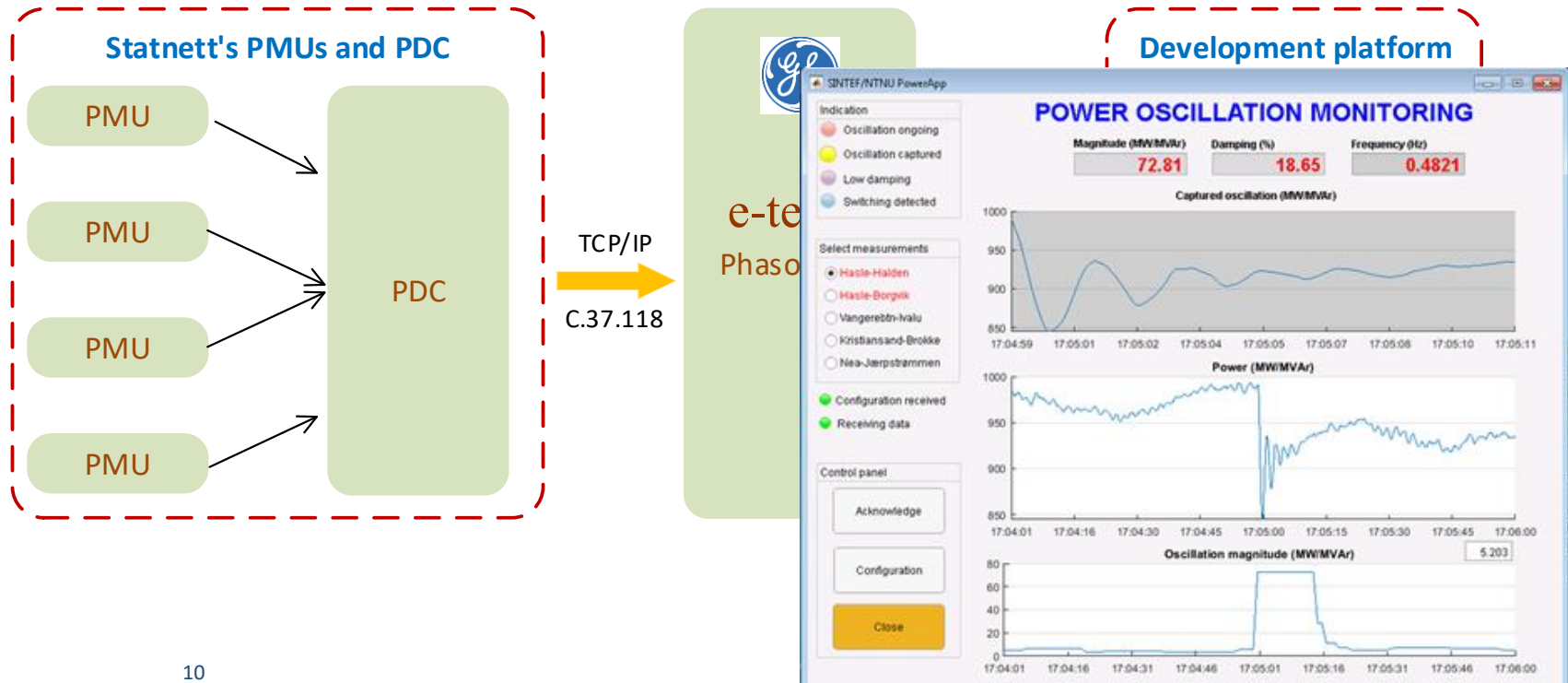
Spandex

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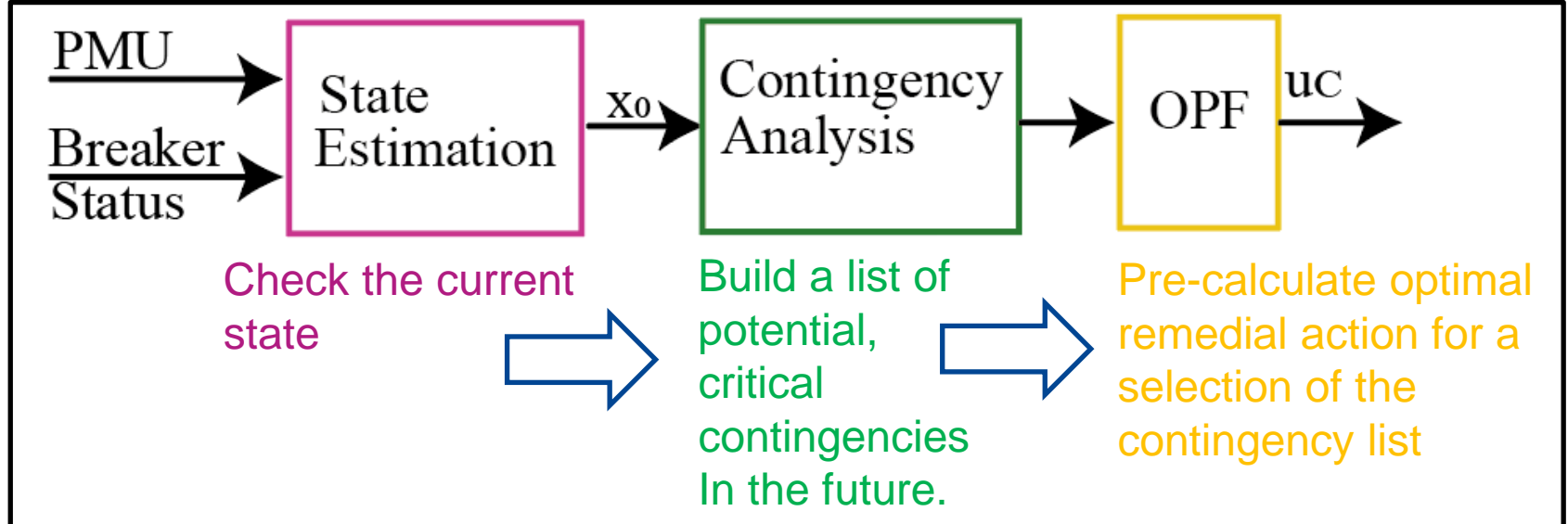


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System Protection Schemes (SPS)

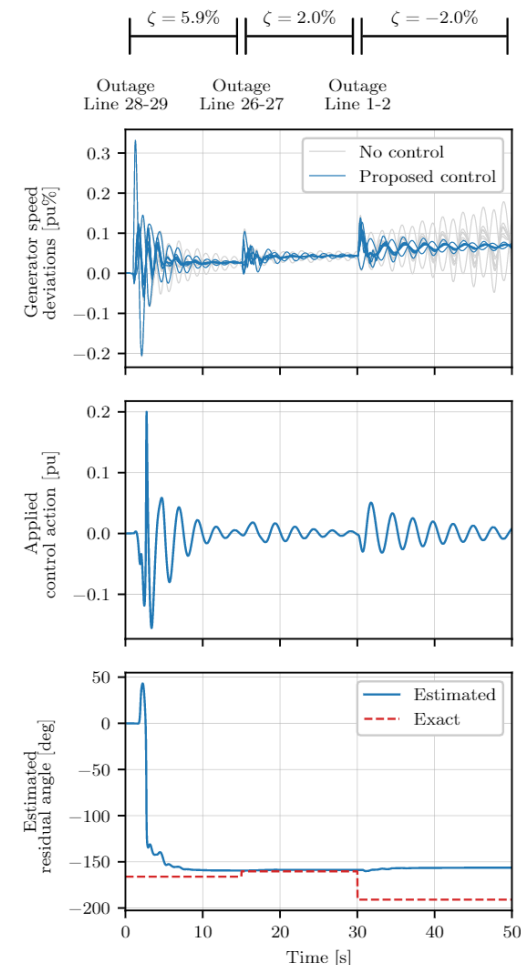
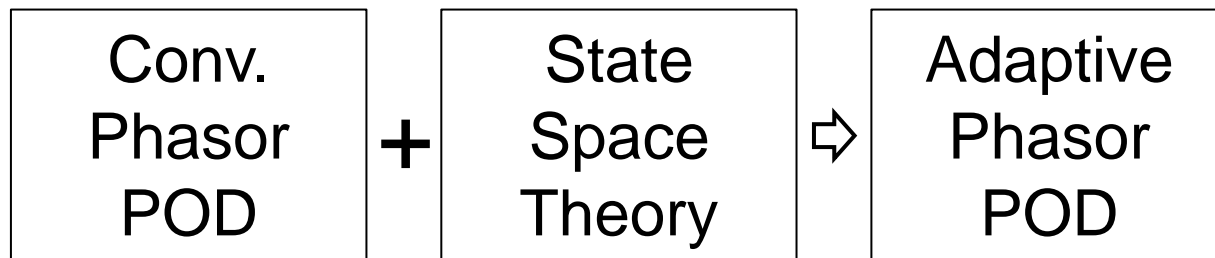
Motivation: Most of installed SPS are rather response based (pre-defined action for a predefined event) [1]. The objective is to design them more adaptive with a mathematically proved optimal control action.



[1] E. Hillberg, F. Trengereid, Ø. Breidablik, K. Uhlen, G. Kjølle, S. Løvlund, & J. O. Gjerde, (2012). System integrity protection schemes – increasing operational security and system capacity. Paris: CIGRE.

Adaptive Power Oscillation Damper

- Estimate optimal phase compensation during changing operating conditions
- Kalman Filter estimator

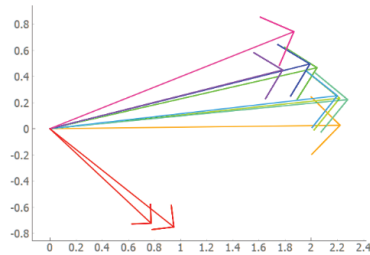


Simulation tool in Python

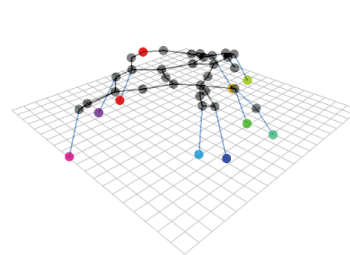
for testing of WAMPAC Applications

- «Real-time» simulation
- RMS quantities
- C37.118

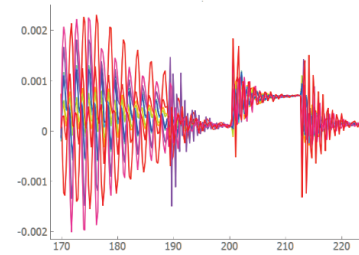
Phasor plot



Grid plot



Time series plot



Line control

| | | |
|---|---|--|
| <input checked="" type="checkbox"/> L1-2 | <input checked="" type="checkbox"/> L4-14 | <input checked="" type="checkbox"/> L9-39 |
| <input checked="" type="checkbox"/> L1-39 | <input checked="" type="checkbox"/> L5-6 | <input checked="" type="checkbox"/> L10-11 |
| <input checked="" type="checkbox"/> L2-3 | <input checked="" type="checkbox"/> L5-8 | <input checked="" type="checkbox"/> L10-13 |
| <input checked="" type="checkbox"/> L2-25 | <input checked="" type="checkbox"/> L6-7 | <input checked="" type="checkbox"/> L13-14 |
| <input checked="" type="checkbox"/> L3-4 | <input checked="" type="checkbox"/> L6-11 | <input checked="" type="checkbox"/> L14-15 |
| <input checked="" type="checkbox"/> L3-18 | <input checked="" type="checkbox"/> L7-8 | <input checked="" type="checkbox"/> L15-16 |
| <input checked="" type="checkbox"/> L4-5 | <input checked="" type="checkbox"/> L8-9 | <input checked="" type="checkbox"/> L16-17 |

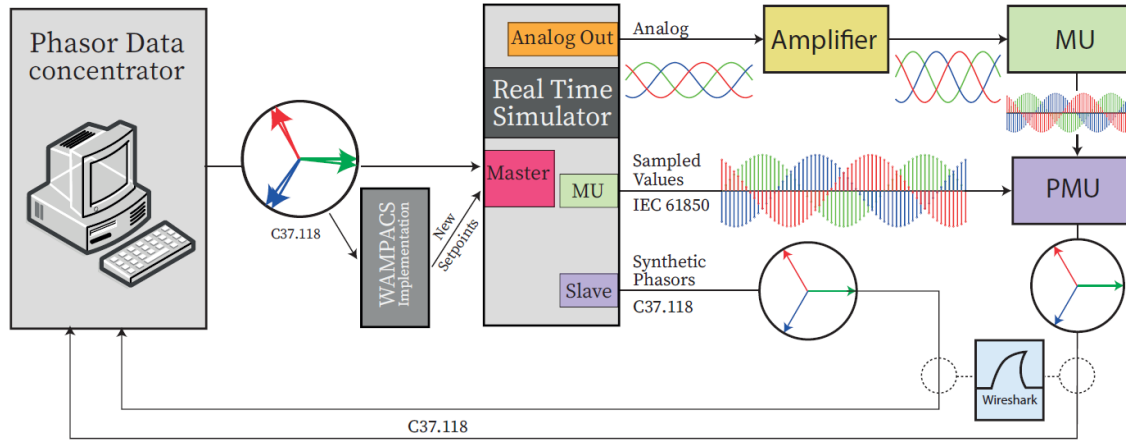
Generator controls

| | | | |
|--------------------------|------|-------|-------|
| <input type="checkbox"/> | SEXS | TGOV1 | STAB1 |
| <input type="checkbox"/> | SEXS | TGOV1 | STAB1 |
| <input type="checkbox"/> | SEXS | TGOV1 | STAB1 |
| <input type="checkbox"/> | SEXS | TGOV1 | STAB1 |
| ⋮ | | | |
| <input type="checkbox"/> | SEXS | TGOV1 | STAB1 |

Event log

```
t=175.6s: PSS on G8 activated.
t=176.0s: PSS on G9 activated.
t=188.9s: Line 2-25 connected.
t=200.4s: Line 2-3 disconnected.
t=212.7s: Line 2-3 connected.
```

Laboratory Work



Description:
 Characterization of the different approaches how PMUs can be included in our real-time setup.

Purpose:
 Evaluate the different paths regarding their behavior (e.g. time delay).

Objective:
 Identify how these differences influence a potential application.

New Nordic R&D project: **NEWEPS - Nordic Early Warning Early Prevention System**

The concept

