Statnett
Forskning og Utvikling
Research and Development

Metrological challenges in the future Transmission Grid

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SVP R&D Statnett

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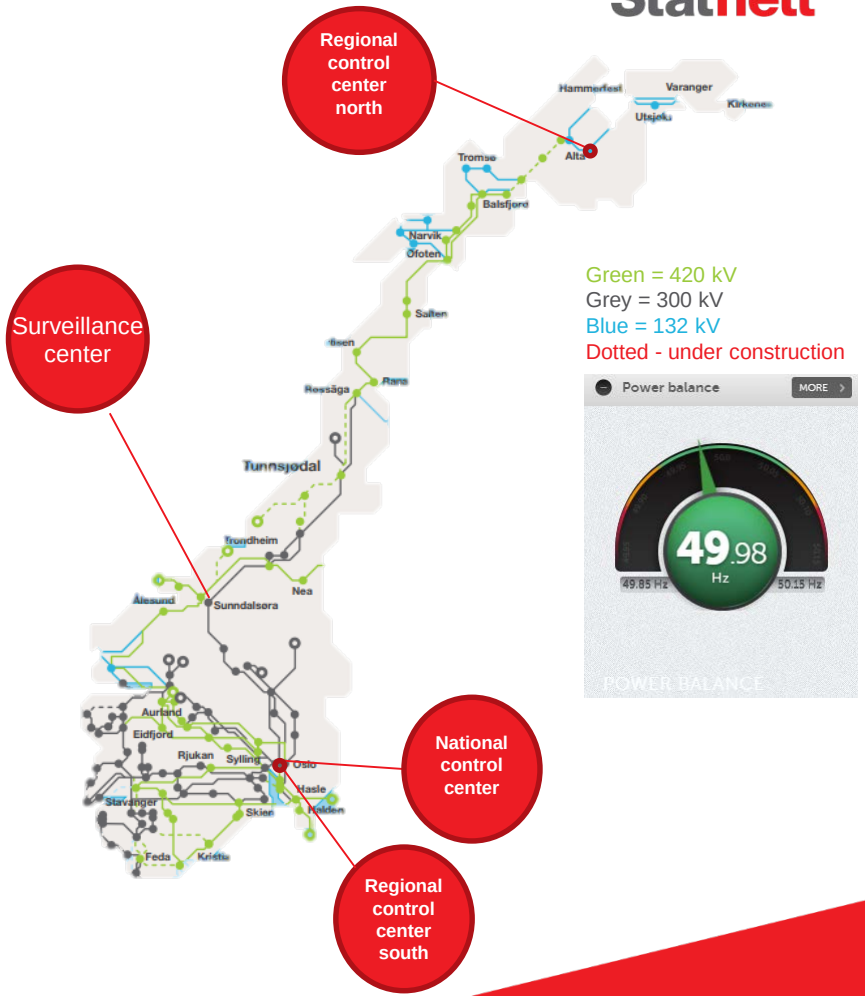
This is **Statnett**

- Statnett is the **Transmission System Operator** in the Norwegian energy system
- Statnett operates and owns about 11 000 km of lines and cables and approximately 150 transformer stations throughout Norway
- Operations are **monitored continuously** by one national control centre and two regional control centres
- Statnett is also responsible for interconnectors to Sweden, Denmark and the Netherlands



In **short**

Everything is dependent on electricity

Our society is already electrified. Electricity is perhaps our most important infrastructure

The future is electric

Electricity is the energy carrier of the future – it is both climate and user friendly

The power system – a balancing act

The power system is constantly put to the test. Operational reliability is our number one priority

Next generation power system

The power system and the transmission grid are among the main arteries of modern society. To facilitate the transition to an electric future necessitates further development of the power system.

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It is all about keeping the lights on..

And it is getting more difficult

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During all (weather) conditions

Heavy icing

Hurricanes

Outage of production units, or critical components

For as low cost as possible

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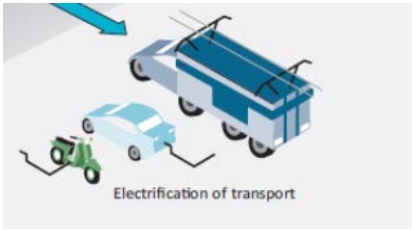
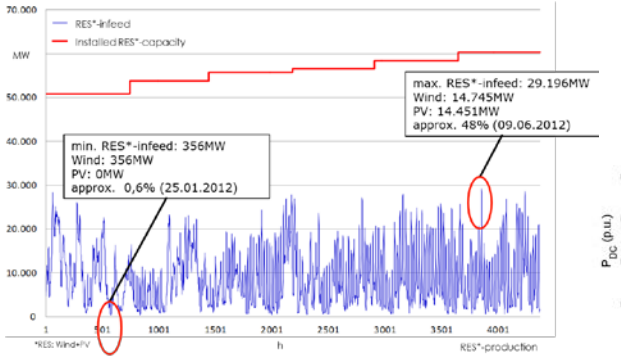
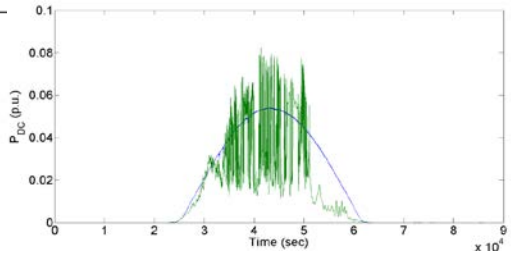
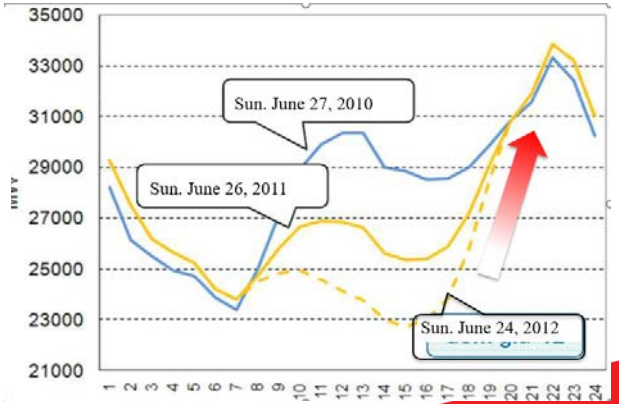
With many uncertainties

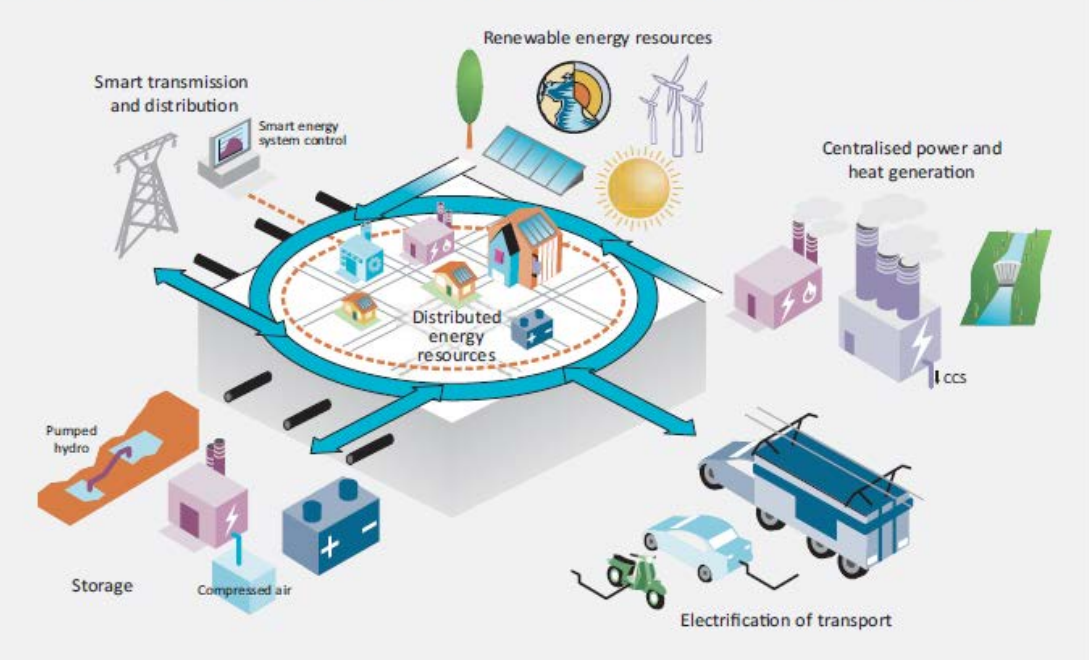






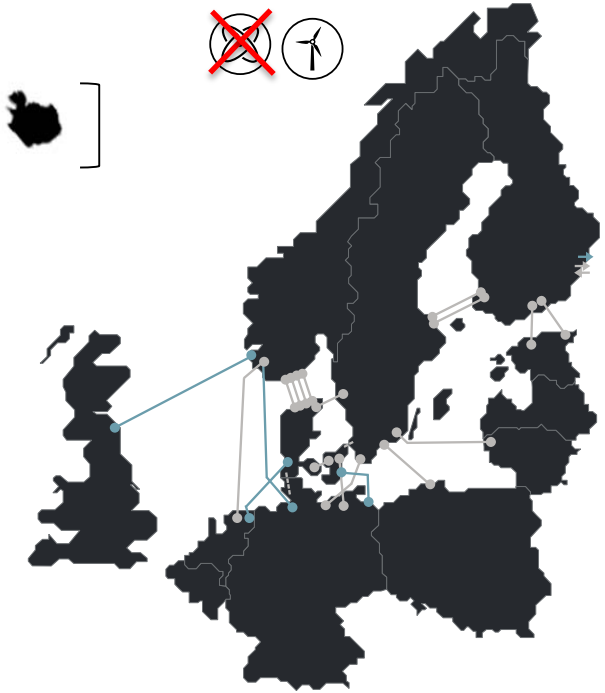


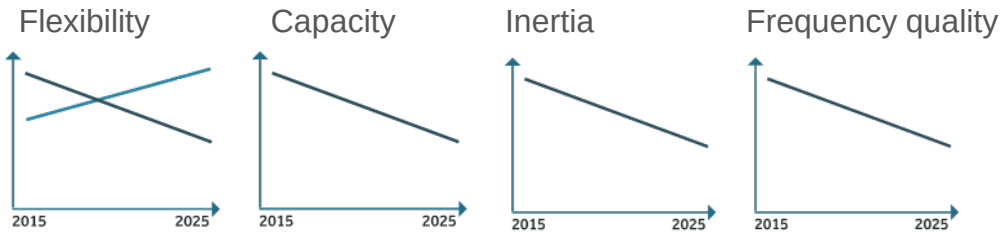
The Next Generation Power System



Source: IEA – ETP 2014 (IEA scenario 2050)

Changes that challenge the way the Nordic Power System is planned and operated





Norway is part of the Nordic synchronous area

import + production = export + consumption + losses

We need more than clean energy production alone

'manual system operation'

1:1 Alert → Action

N:1 Cockpit functionality needed

'automatic system operation'

Increased complexity → **Observability Availability** → **Analytics** → **Real time**

Traditional: Detailed manual control 1:1

Needed: Control Strategy and Automation 1:N

We need full insight and control – at all times

How to achieve full insight and control?

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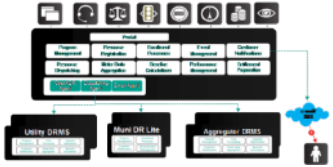
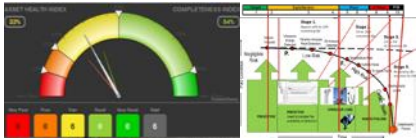
Dashboards



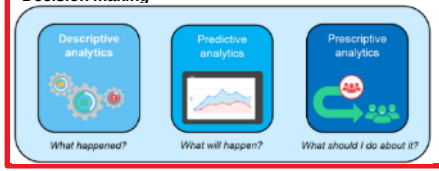
Large scale demand response

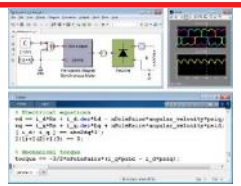
WAMS /WAPS

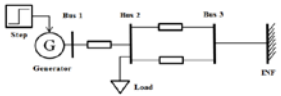


SAMBA

Decision making







Complete **models** of the power system and its components with regards to aging, dynamics, performance and failure mechanisms.

Real-time decision support

Big Data

No restrictions in **communication technology** and data harvesting, processing and storage

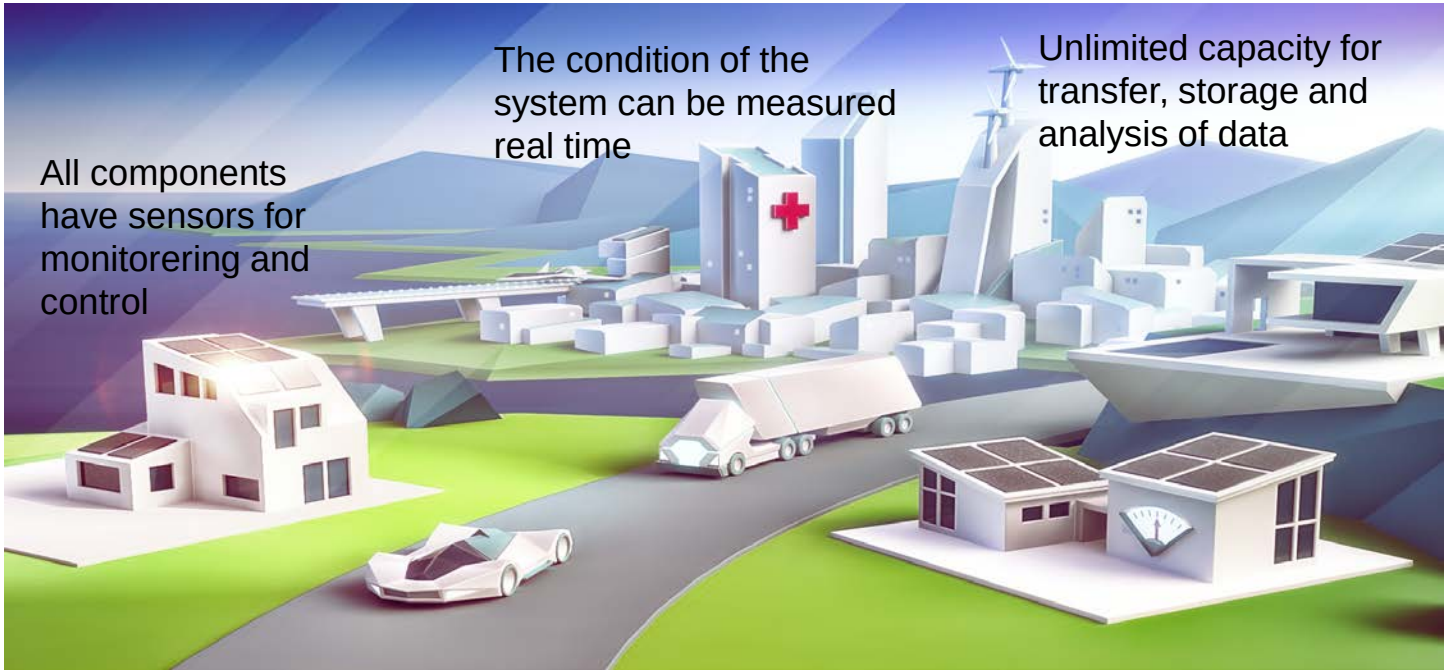
Control

Monitoring

Sensors measure all primary and secondary parameters:

Voltage, power, phase angles, pressure and temperatures, humidity, vibrations

This means that ICT, measurements and data will have a dominating role in the Next Generation Power System



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Our challenges are (too?) many

In which areas are we already working?

- ENTSO-E RDIC has divided
  - Power System Modernisation
  - Security and System Stability
  - Power System Flexibility
  - Power System Economics and
  - ICT & Digitalisation of the Powe

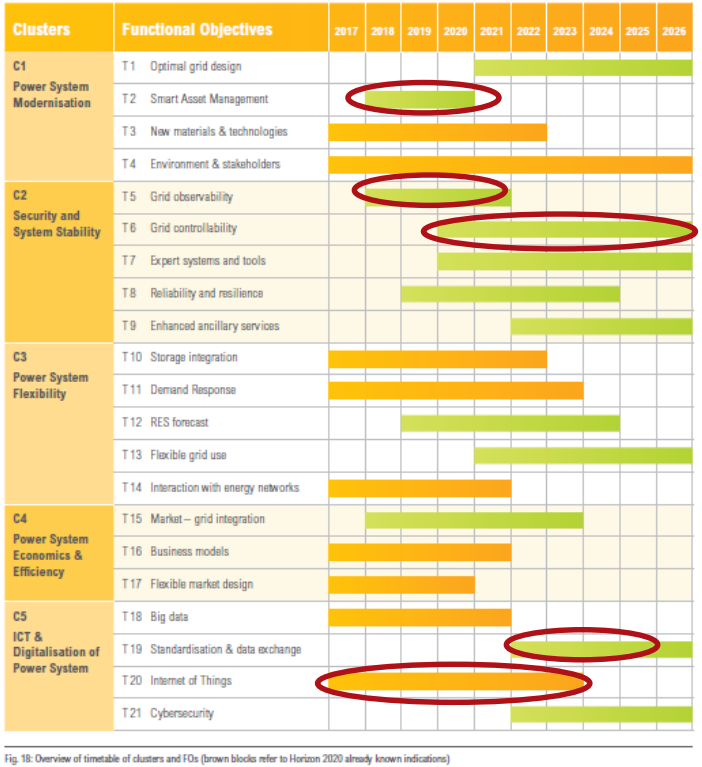

Fig. 18: Overview of timetable of clusters and FOs (brown blocks refer to Horizon 2020 already known indications)

Areas with high R&I priority

1. Asset management
2. Joint TSO/DSO activities and improved coordination between boundary grids
3. Market design

European Network of Transmission System Operators for Electricity

entsoe

Area 1 – Asset management

- **Asset management** aims to validate the benefit of individual lifetime condition and life expectation assessment compared to an average assessment of several similar components based on generic parameters (age of equipment, switching steps, etc.) and to establish evaluation/estimation protocols for component statuses that are comparable across TSOs.
  In addition, maintenance activities with the network ‘live’, and implementation of devices and robotics for problem detection deserve to be addressed.

Area 2 – TSO/DSO activities

- **Joint TSO/DSO activities and improved coordination between boundary grids** aim to develop simulation tools and methods that detect weaknesses in the system with respect to the reconnection of DER and storage systems and the risk of breakdowns caused by reconnection. Emerging ancillary services from aggregated small-energy sources and demand response and management at the DSO level provide extra means and system services for TSO operation. New modelling methods and tools for steady-state and dynamic analyses should also be developed.

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Area 3 – Market design

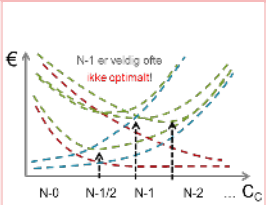
- **Market design** aims to investigate interactions among system operations, dynamic capacity, reserve allocation methods, and design grid tariff mechanisms for active demand-side management and to correlate the load curve and integration of renewable energy sources at the regional and pan-European levels.

Sustainable System Development

Climate and Environment

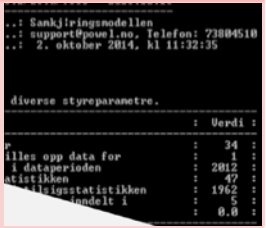
Cost-effective development of power systems

Probabilistic risk assessment



Greener construction work

Model development



Smart grid development

Innovative Technology

20 % faster

20 % safer

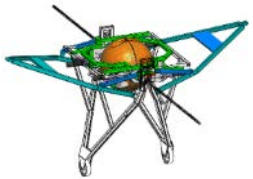
20 % cheaper

Aluminum and composite pylons

Digital substation

ICEBOX

Installing markers using a robot

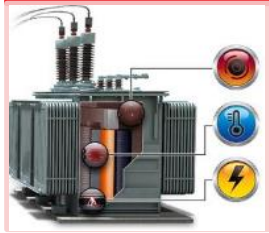


Smart Grid

Better utilization of the grid

Safer and cheaper operation

Smart asset management



Smart operation

Pilot Northern Norway

Smart surveillance

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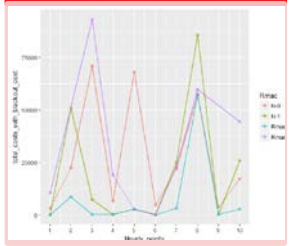
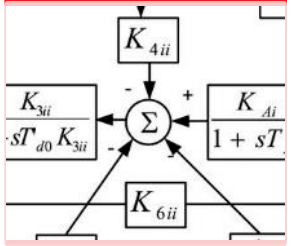
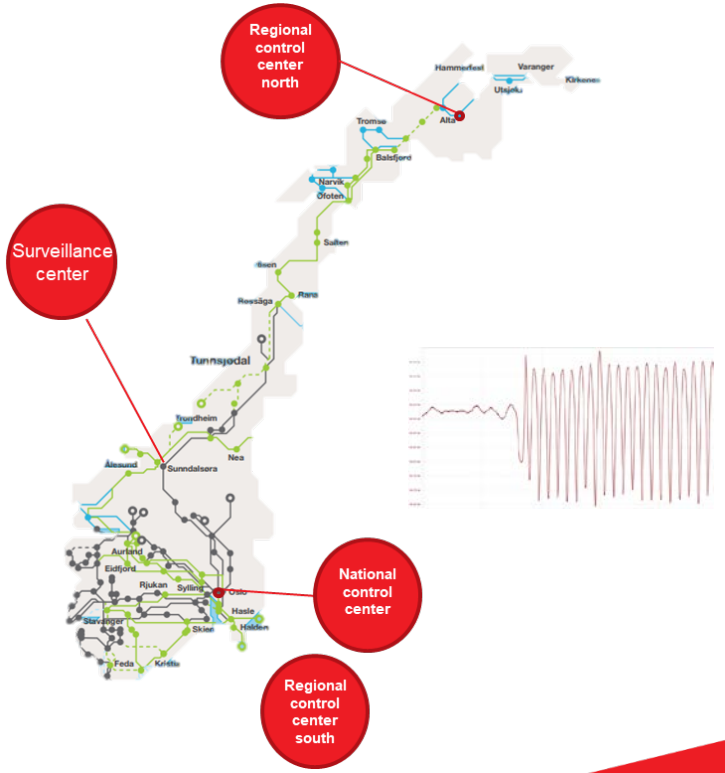
Our areas of digitalization

Robots	Self-diagnosis	Digital infrastructure	Cyber physical security
			

Faster response	Prediction	Model development	User interface
			

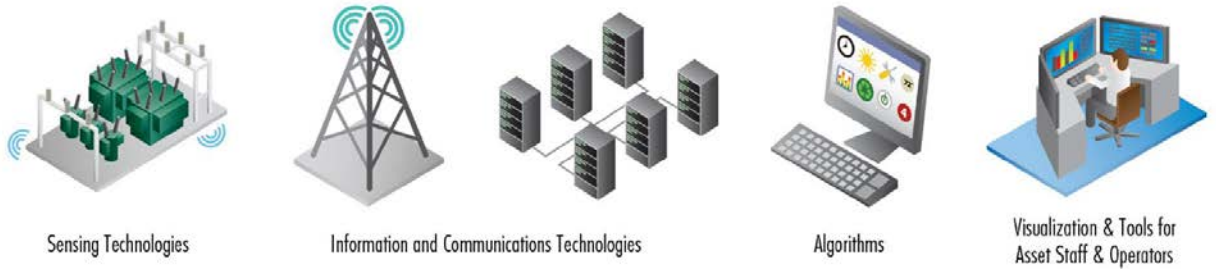
Where and for what do we need measurements?

- The National Control Center
  - 'Keeping the balance'
- Regional Control Center
  - 'Voltage and stability'
- The Surveillance Center
  - 'Asset management'



From sensor to decission support

- What are the right measurements?
- Do you dare to take a component out of service based on the data from one or more sensor?



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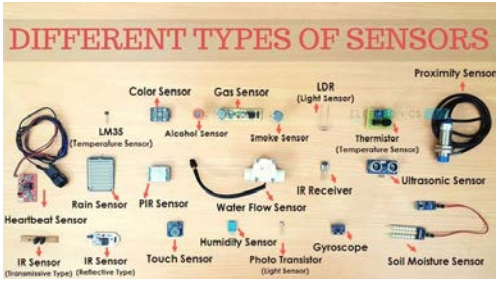
High requirements to measurements

- Data quality is one of our major challenges
- Sensors and Measurements should NOT:
  - Reduce life time
  - Endanger security of supply
  - Lead to a need for replacing the whole component
  - Increase risks for cyber security
- They should:
  - Provide accurate and real time data
  - Be fast, reliable
  - Be compatible with TSO infrastructure
  - Allow for probabilistic operation and asset management

Sensing Technologies

What kind of measurements are needed?

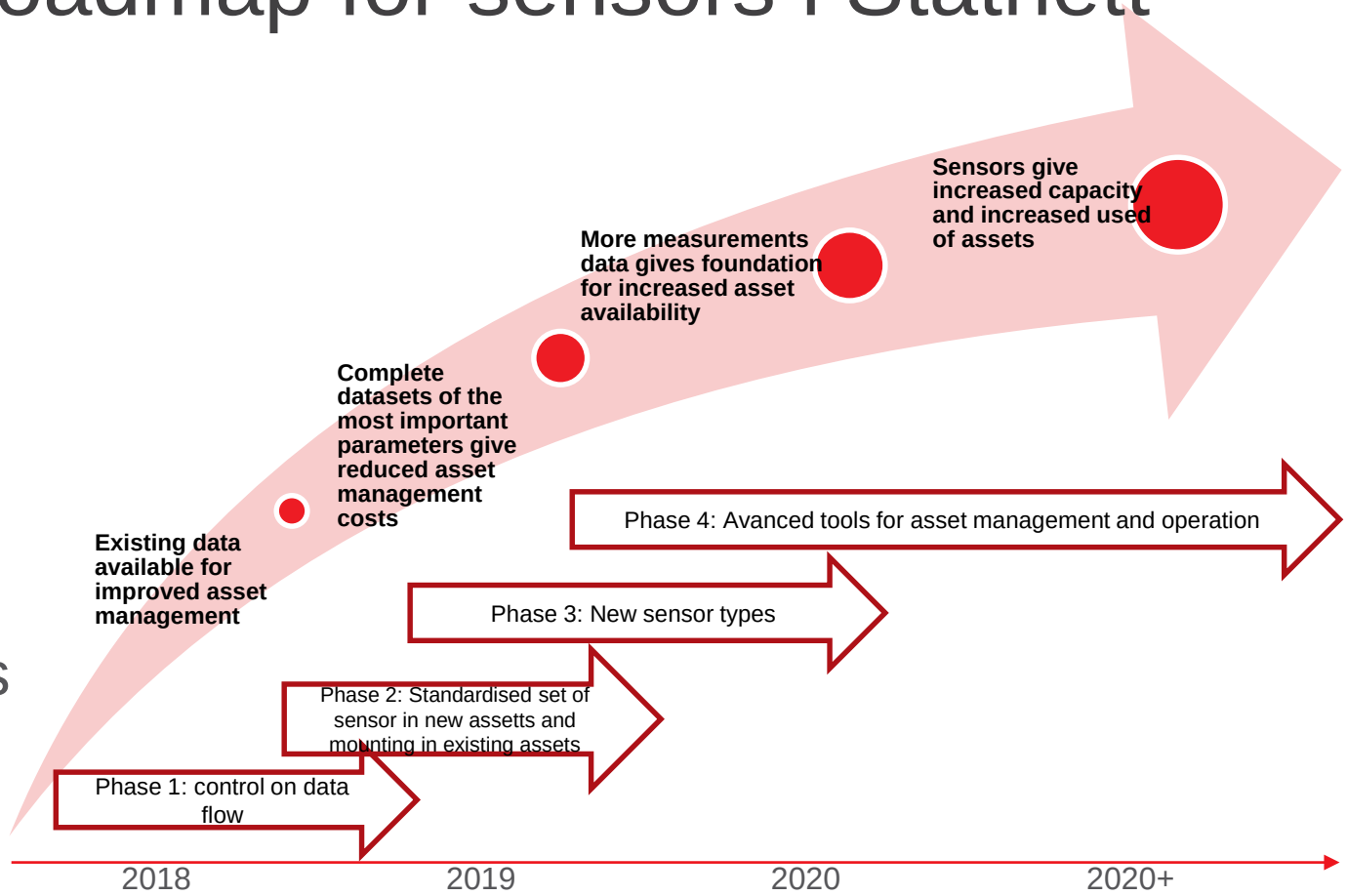
- Examples are:
  - Time measurements
  - Weather measurements
    - Lightning
    - Temperature
    - Wind
    - Ice
    - Solar radiation
  - PMU
    At this moment they do not give the same output – better standard is needed
  - Power Quality instruments
  - Different sensors
    Certification of sensors for the power industry is needed
  - EMC measurements
  - Vibration measurements
  - Current, Voltage measurements in digital components
  - Measurements for improving models
  - Positioning by GPS
    - For machines, robots and animals (goats, reindeer, birds)



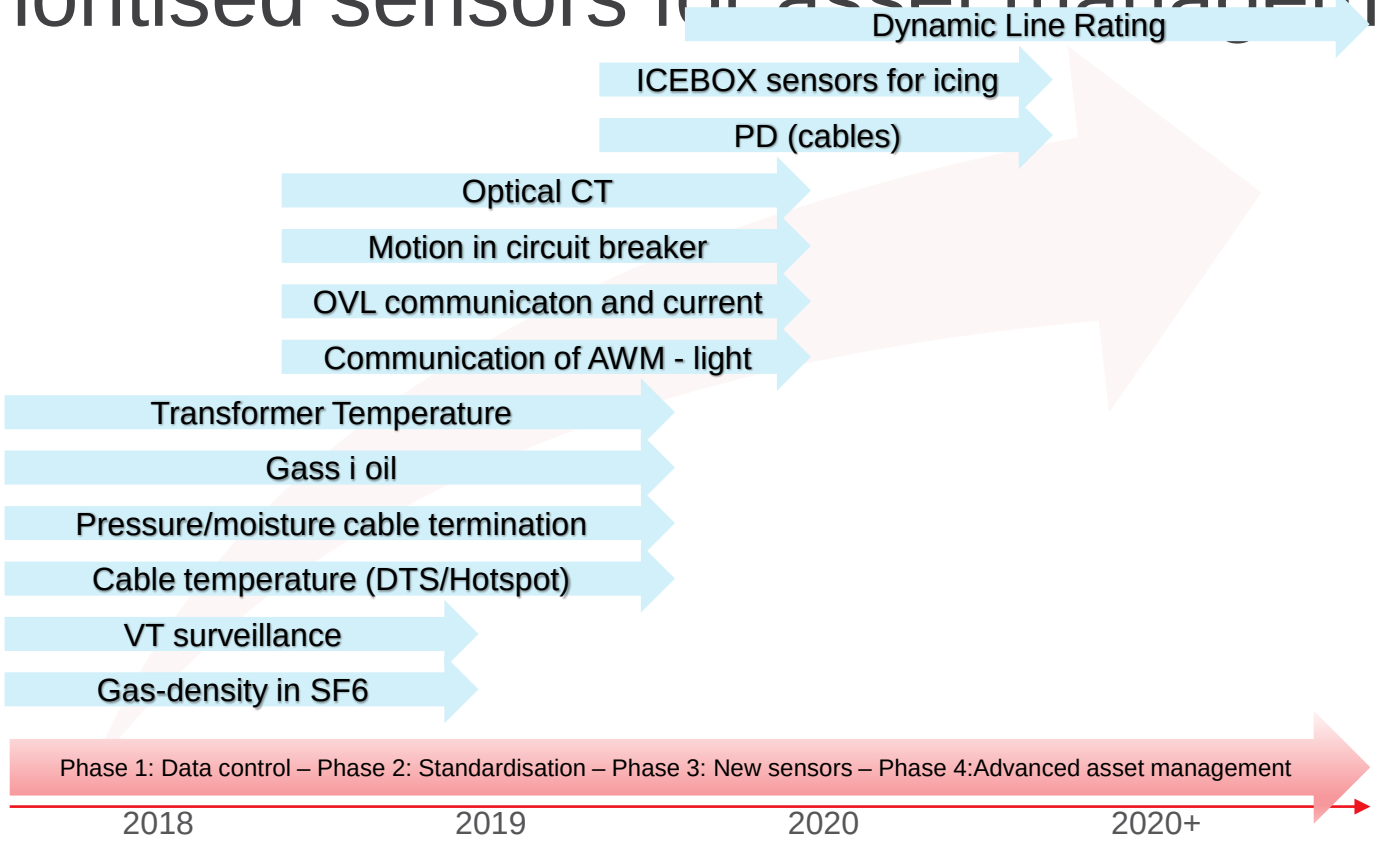
Roadmap for sensors i Statnett

Goal

Activities



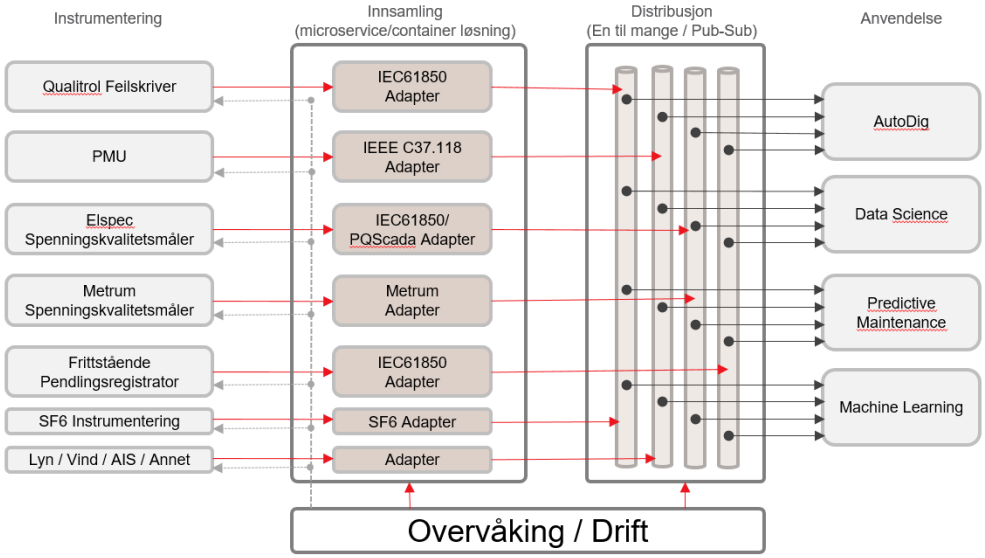
Prioritised sensors for asset management



Compatibility with infrastructure

- Cyber security
- Standardisation
  - measurements
  - communication

Illustrasjon av fremtidig innsamlingsinfrastruktur



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Some examples for inspiration

COSECTIME

- To increase time accuracy and increase cyber security we need better methods for measuring and distribution of time
- Atom clocks and IEEE1588 PTP

Priority	Source	Status	Offset
01	PTP (IEEE1588)	Signal available, is master	+0.0ns
02	GLONASS/GPS Receiver	Signal available	-14.0ns
03	ext. Osc.	Signal available	-16.0ns [+19.0ns]
-	PPS in	Not prioritized	N/A
-	IRIG	Not prioritized	N/A
-	NTP	Not prioritized	N/A
-	Fixed Freq. in	Not prioritized	N/A
-	PPS plus string	Not prioritized	N/A

Digital substation

Why?

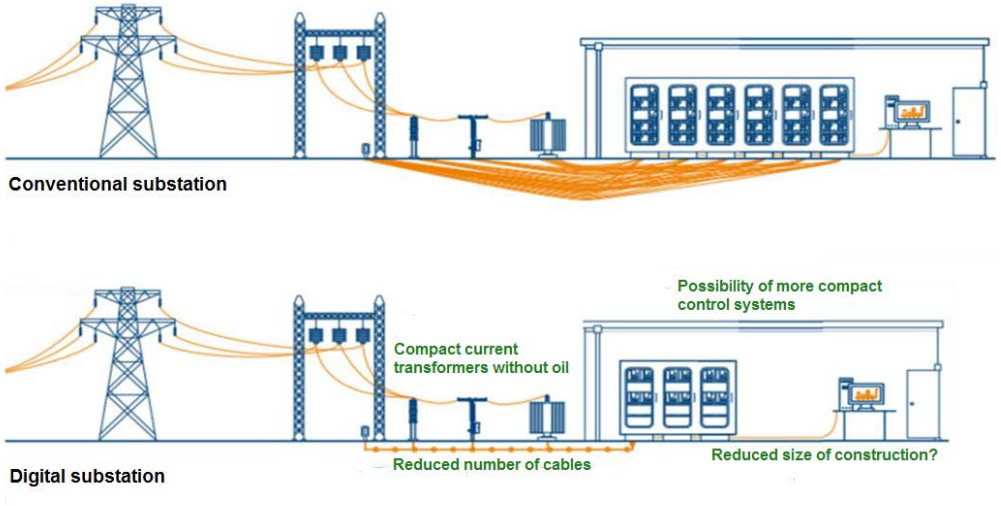
- Statnett has to reinvest in a lot of substations to be prepared for the future's power system in the coming years

Goal

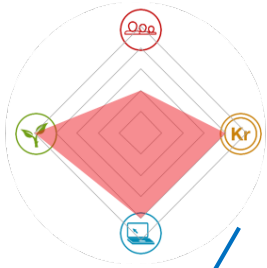
- A full digital substation where the control system is installed in three weeks instead of one year

Where are we now?

- A pilot located at Furuset is operative



Installing aircraft warning markers using a robot



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Why?

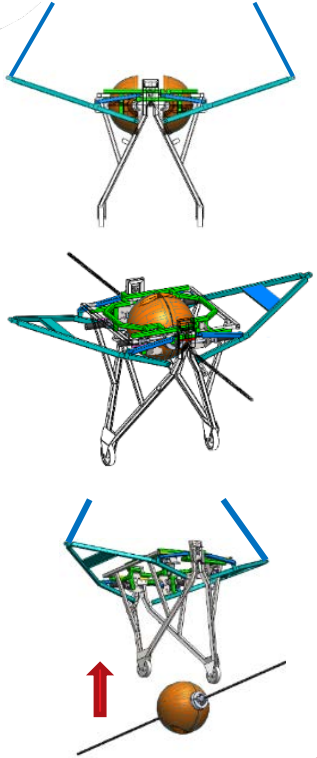
- Statnett replaces and installs aircraft warning markers all the time
- The current method is time consuming, requires work at height and costly outages

Goal

- Develop a method that is more
  - Safe → no more working at height
  - Faster → from one week to hours
  - Cheaper → reduced need for outages

Where are we now?

- The first 130 markers are installed with robot



DALEKOVOD

Best Paths PROJECT

INNOVA

MOSDORFER

SPACERBOT

Why?

- Statnett installs spacers on new lines, and replaces old ones on existing lines

Goal

- A safer, faster and cheaper method for installing spacers

Where are we now?

- The project is expected to start soon

Composite utility pole

Development of composite utility poles for 420 kV transmission towers

Why?

- Statnett wants safer and cheaper pylons that can be built faster

Goal

- Develop a composite pole for 420 kV
  - Simple visual expression
  - Light weight
- Reduced number of helicopter flights
  - Shorter construction duration
  - Increased safety

Where are we now?

- 25 m prototype of pole leg has been tested
- Next step is to complete the design phase and test the entire pole

Alumast

Design of aluminum pylons adapted to automated production

Why?

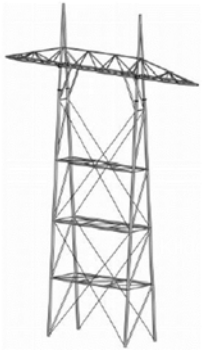
- Statnett wants safer and cheaper pylon solutions that can be built faster

Goal

- Increased safety, reduced cost
- New methods for calculation and manufacturing
- Increased value throughout the value chain
- Effective working method

Where are we now?

- Aluminium pylon designed, produced and tested in 2017
- The prototype passed the tests for load and vibrations



Oppland Arbeiderblad 10.24.2017

Alma

11 000 kg -> 5000 kg

KAPP ALUMINIUM TRETUM OFFSHORE

Forskningsrådet

MIND Cables

Mass Impregnated Cables

Why?

- Need to learn more about how the capacity of cables can be better utilized

Goal

- Increase the transmission capacity of new MIND HVDC cables from 840 MW to 1.1 GW
- Define operational limits for existing cables

Where are we now?

- The project has started

ICEBOX

Ice monitoring, forecasting, mapping, prevention and removal toolbox

Why?

- Ice on components is a serious problem
  - Components are not dimensioned for the ice load → breakdown and power outages

Goal

- Reduce the icing problems significantly by better
  - dimensioning tools
  - surveillance and prediction methods
  - ice removing and anti icing technology

Where are we now?

- The project is in start-up phase

CICERO Senter for klimaforskning · NCAR · EFLA · UiO · Universitetet i Tromsø · Forskningsrådet · KJELLER VINDTEKNIKK · LANDSNET · I²G INDEPENDENT INSULATION GROUP

SAMBA

Smarter Asset Management with Big datA

Why?

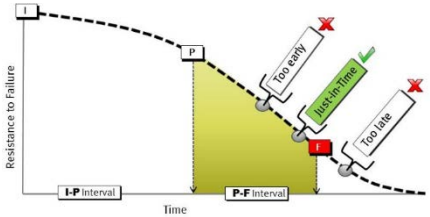
- With a smarter asset management, Statnett will save money and increase HSE

Goal

- A maintenance and reinvestment regime based on knowledge
- Better utilization of data, and more efficient data collection

Where are we now?

- The project has contributed to a new smart asset management strategy in Statnett
- Test of different models and methods of condition evaluation



SPANDEx

Synchrophasor/**P**MU **A**pplication I**n**tegration and **D**ata **Ex**change

Why?

- Larger, more frequent and more unpredictable power fluctuations are challenging for system operation

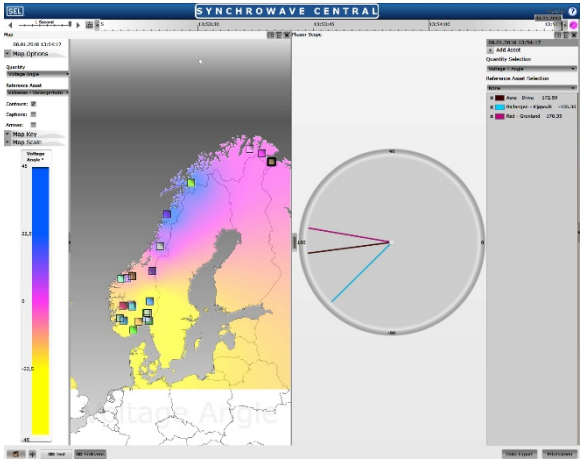
Goal

- Better control of the power flow
  - Testing existing PMU applications and developing new → introduce PMUs in operational mode
  - Transition from surveillance to protection and control

Where are we now?

- PhasorPoint is configured and the system control centers have received training
- Test of voltage stability application
- Development of new applications

PMU
- Phasor Measurement Unit
- Measures phase angle and amplitude of current and voltage 50 times per second



IMPALA

Predicting power system imbalances with machine learning

Why?

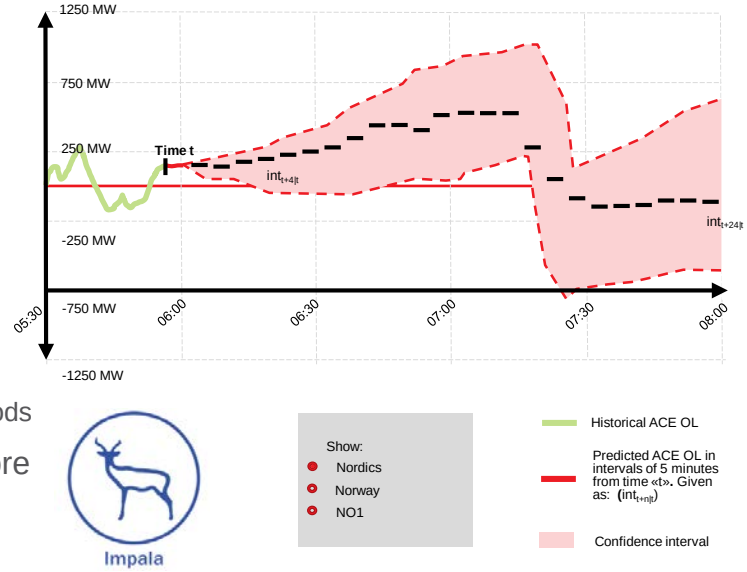
- Use machine learning to predict imbalances in power systems

Goal

- Increased frequency quality using **artificial intelligence**

Where are we now?

- A prototype that uses external data to predict how imbalances will evolve
  - 25-75% better than the national control center's existing methods
- The project will expand the data access to develop a more accurate model



Pilot Northern Norway

Large scale testing of functionality for remote disconnection of loads

Why?

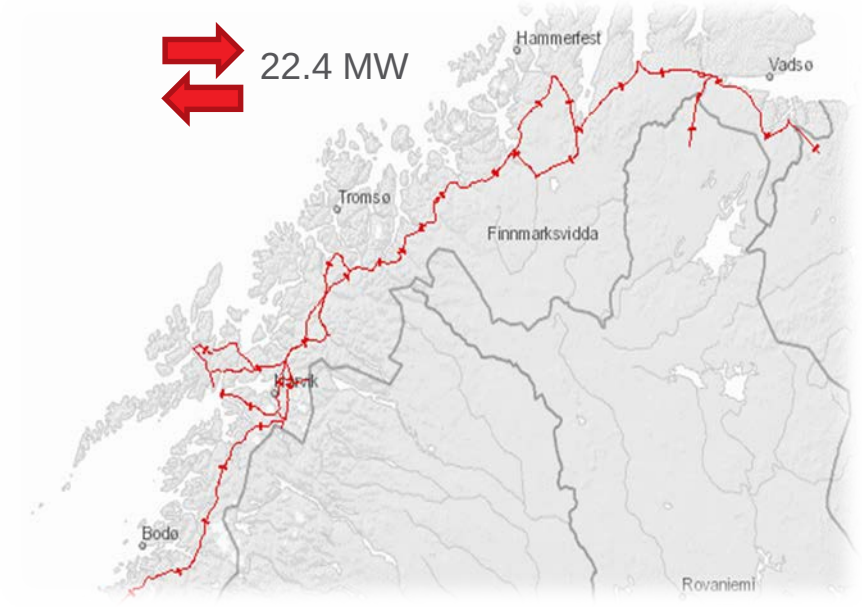
- Operations centers need new means to increase security of supply in strained operating situations

Goal

- Functionality for remote disconnection of consumption in the distribution network

Where are we now?

- Test period Q1 2018: large scale pilot where 22.4 MW can be disconnected from the control center



Drones

Why?

- Drones can make it possible to collect data safer and more effectively, but there are still some challenges that have to be solved

Goal – to use drones for:

- Inspection of components
- Identify fault location
- Documentation of construction work and fault locations

Where are we now?

- Three projects starting up
  - Autonomous flight along line to the fault location
  - Autonomous flight inside stations
  - Autonomous flight, artificial intelligence, digital platform, communication and data storage
- Technology qualification
  - Service catalog for drone operations

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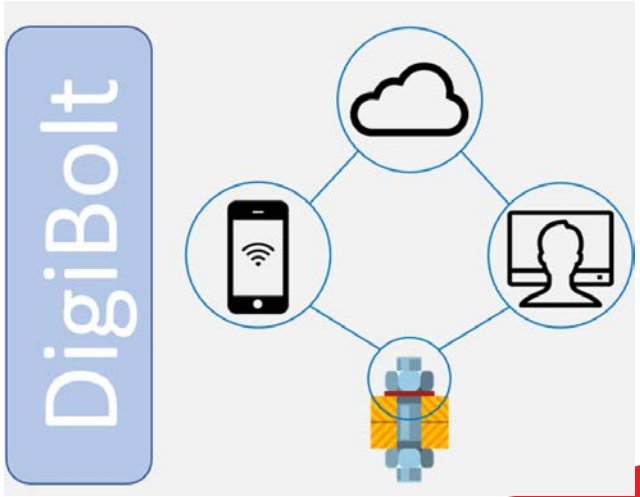
Vibration measurements

No working measurement method

Digibolt – digital tension monitoring

- Large important constructions are held together with thousands of critical bolts
  - Cranes, process plants, bridges, shipping, wind turbines, masts etc
  - Example: Oil and gas production platform: 300 000 critical bolts
- Important that critical bolts have the correct pre-tension and the correct tension over time.
- DigiBolt supports this by having a sensor built into the washer which passively measures the tension the washer is subject to. The tension can either be read out manually or by making an autonomous read-out and communicating system.

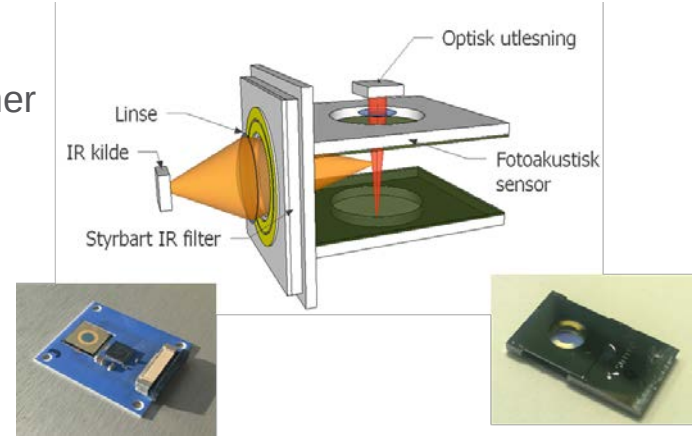
Project proposed by. Veritrack, Tingstad, SINTEF, Tronrud



Gas monitoring of transformer oil

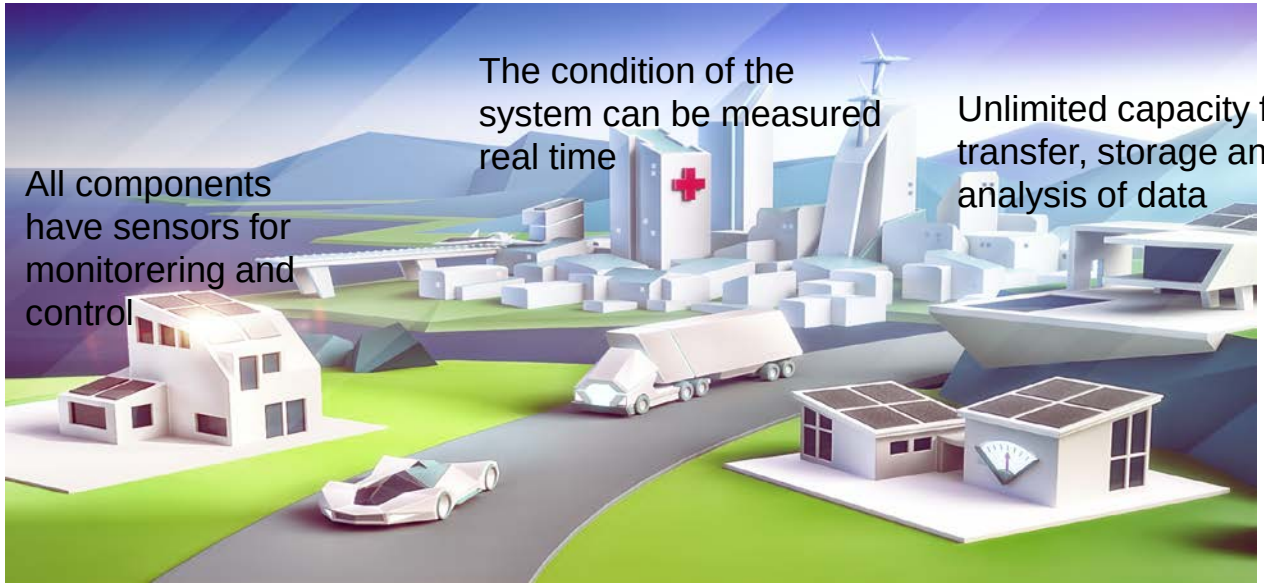
- Goal is to develop an on-line gas monitoring solution
- Will measure 8-9 of the most relevant gasses

- Estimate for economic cost reduction
  - 10 -20 % increased lifetime => 3 MNOK per transformer
  - 200 transformers => 600 MNOK
  - 4 000 transformers => 12 000 MNOK (in Norway)



Statnett

Measurements, measurement data and analysis will have a dominating role in the Next Generation Power System



Don't be afraid to contact us if you have an idea

We can help identify right partners and might test the solution in our system

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