



## PowerLabDK

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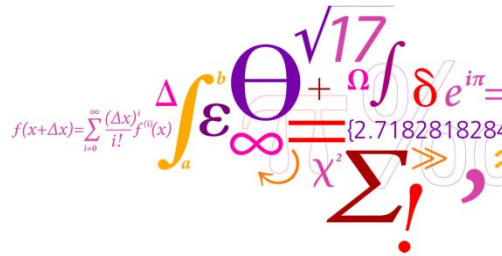
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## PowerLabDK

Professor og centerleder  
Jacob Østergaard

14. januar 2013



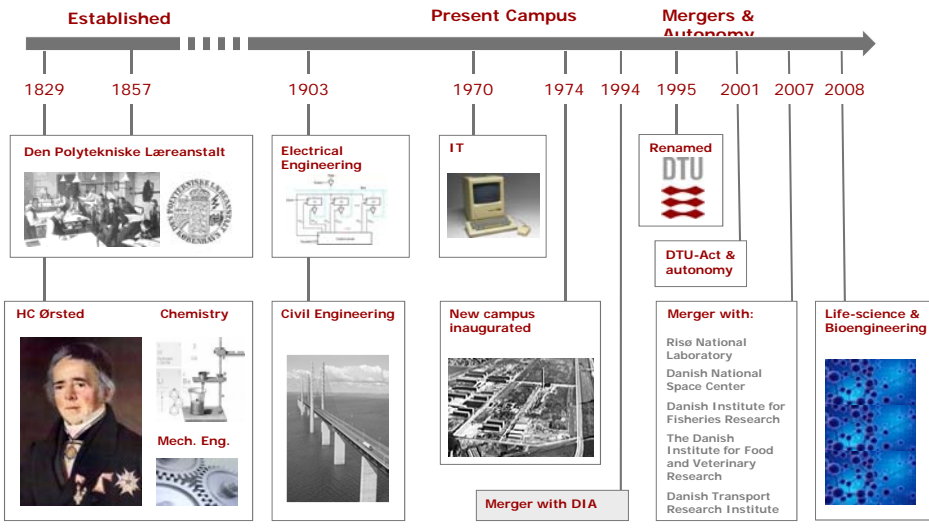
DTU Electrical Engineering  
Department of Electrical Engineering

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## Agenda

1. Introduction to DTU and Center for Electric Power and Energy
2. PowerLabDK faciliteterne
3. Muligheder for F&U
4. Ny rammeaftale om udnyttelse af PowerLabDK's faciliteterne
5. IEEE ISGT Europe 2013
6. Nedbrud Bornholm

## History of DTU – a short introduction



## DTU Mission

DTU will develop and create value using the natural sciences and the technical sciences to benefit society



# DTU



DTU Lyngby Campus



DTU Risø Campus



Scion DTU



DTU Vet/Food/Aqua



DTU Høvsøre/Østerild



DTU DANA



## Key figures

Students	7.600
Ph.d.'s	1.300
Staff	5.000
Budget	605 MEuro

## Energy Research and Education at DTU



- ~1.000 researchers, including faculty, senior scientists, PhDs and technical staff in energy R&D
- Sustainability, climate and renewable energy technologies are integrated in DTU's portfolio of BSc and MSc programs
- DTU's offers 5 dedicated energy MSc programs
  - Wind Energy
  - Sustainable Energy
  - Petroleum Engineering
  - Nordic Master in Innovative and Sustainable Energy Engineering
  - Erasmus Mundus European Wind Master

## Center for Electric Power and Energy (CEE) Department of Electrical Engineering

- CEE established 15 August 2012 as a merger of existing units:
  - Center for Electric Technology, DTU Electrical Engineering
  - Intelligent Energy Systems, Risø National Laboratory for Sustainable Energy
- Main competences
  - Electric Power Engineering
  - Automation and control
  - Information and Communication Technology
- A strong university centers within its field
  - Staff: 85 persons incl. PhD-students
  - Covers discipline oriented research as well as national lab type application-driven research and proof-of-concept
- Strategic partnerships



## Strong National and International Collaboration Selected Partners

### • Academic partners:



### • Commercial and industrial partners:



### • Networks:



## Center for Electric Power and Energy (CEE) Strategy under development (tentative)

### Mission



*To provide cutting-edge research, innovation and education within electric power and energy to meet the future needs of society regarding a reliable, cost efficient and environmentally friendly energy system.*

### Vision



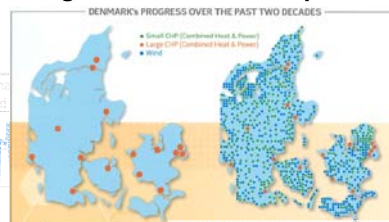
*To stand out as a dynamic, open and internationally recognized center of collaborating scientists, students and engineers generating a strong scientific, societal and industrial impact.*

## Some Main Research Challenges (and The Danish Wind Power Case)

### Balancing:



### Changed Generation Landscape:



### Stability and Reliability:



### Cost effective solutions:

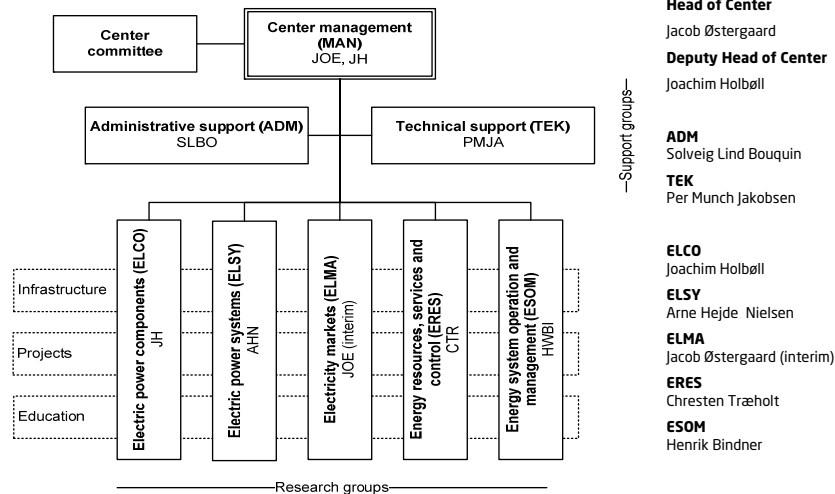


## Research Groups of CEE

- Electric Components
- Energy Resources, Services and Control
- Energy System Operation and Management
- Electric Power Systems
- Electricity Markets



## Center for Electric Power and Energy Organisation



## PowerLabDK combines experimental facilities

**Flexible multi-purpose laboratories**

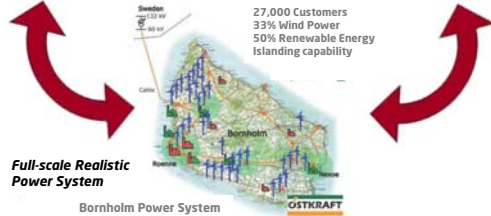


Lyngby & Ballerup Campus

**Large-scale test system**



Risø Campus



**Full-scale Realistic Power System**

Bornholm Power System

Stakeholders:



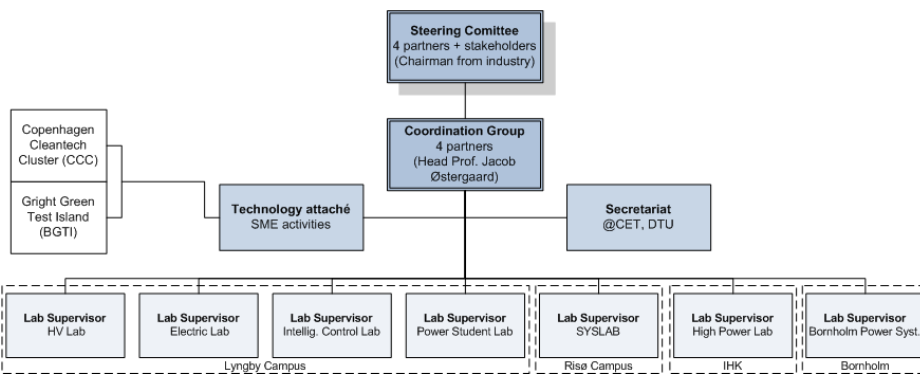
Supported by:



Investment:

18 million Euro

## PowerLabDK Organisation





## PowerLabDK Concept of Use Self Service Garage Model

Self Service. Full Service. You Decide.

Full MOT from £35 (class IV V VII)  
Servicing and repairs by fully trained mechanics from £45 per hour  
Europe's largest fully equipped self service garage: from £10 per hour  
Open 7 Days a Week

SAVE UP TO 50%  
ON MAIN DEALERSHIP CHARGES  
FOR ALL SERVICING & REPAIRS

CURRENT OFFER  
All day ramp for only £80

020 8827 1919 · 36 Standard Road, Park Royal Industrial Estate, Acton, London NW10 6EU. Please note that advanced reservations are required for using the premises between 10pm and 8am. ©2011 Pitstart Self Service Garage. All rights reserved.

Self Service. Full Service. You Decide.

15 DTU Electrical Engineering, Technical University of Denmark

Presentation name 17/04/2008

## Eight PowerLabDK Facilities From Basic Research to Full-Scale Real-life Experiments

Bornholm Power System	Full-scale laboratory including 27,000 customers, 33% wind power
Electric Lab	Flexible interconnectable lab cells with ICT-infrastructure and central sources
High Power Lab	Continuous high power capability
High Voltage Lab	High voltage and high current generators
Intelligent Control Lab	SCADA-systems, control room, real-time simulator, supercomputer
Power Student Lab	Experimental facilities for teaching and education
SYSLAB	Renewable energy technologies, distributed ICT and control platform
Power Flex Houses	Flexible energy demand, building automation

All is tied together by ICT, SCADA etc.

16 DTU Electrical Engineering, Technical University of Denmark

Presentation name 17/04/2008

**PowerLabDK** 

## Intelligent Control Lab

Power system simulation, control and supervision



[www.powerlab.dk](http://www.powerlab.dk) 

 Technical University of Denmark
 
 energi til gode oplevelser



## Real-Time Digital Simulator Facility (Phase 1)

- 40 CPU cores: 20 GPC-card (each 2xIBM Processor), 110+ buses
- Typical simulation time step 50  $\mu$ s (time step can be down to a few  $\mu$ s depending on the network complexity)
- 1 x GTNET-card
  - IEC61850 standard / IEC61850-9-2 sampled values
  - Playback from PC hard drive
  - SCADA-interface (DNP3 slave)
    - 1024 binary simulation status points (i.e. breaker position)
    - 512 binary simulation control points (i.e. breaker commands)
    - 500 analogue status points (i.e. output from RTDS)
    - 100 analogue control (i.e. input to RTDS)
- I/O-cards
  - 3 x GTA0-card (3x12 analogue outputs  $\pm 10$ V)
  - 3 x GTAI-card (3x12 analogue inputs  $\pm 10$ V)
  - 3 x GTDI-card (3x64 digital inputs channels)
  - 3 x GTDO-card (3x64 digital output channels)
  - 3 x 16 dry contact outputs (0-250 Vdc)
- GPS-clock
- Programming
  - GUI-based RSCAD
  - Standard power component library, generator control library, control library, automation and protection library, and small time power component library for control study of power electronics
  - Cbuilder - User defined models, based on C Language
  - Import study case from PSS/E



## Real-time Digital Simulator

- A highly specialized digital computer dedicated for real time dynamic simulation of power systems and interaction with external hardware
- Application
  - Analysis of transmission and distribution networks
  - Protective relay and control system testing (hardware-in-loop)
  - Operator training and control room solutions (operator-in-loop)
  - Power equipment test under realistic grid conditions (power hardware-in-the-loop)
  - IEC 61850 tests
  - Integrated experiments with operator, control room, simulated grid, physical controllers and power equipment in the lab



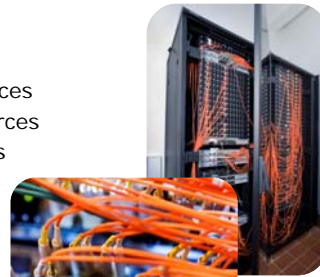
## Control Room

- *Full-scale power system control room for development of applications without disturbing real customers.*
- Application
  - Power system operation
  - Operator training
  - SCADA and EMS applications
  - Human-machine interface
  - Data collection from field
  - Supervision and control of experiments



## Communication Network PowerLabDK @ DTU Lyngby Campus

- Four communication networks
  - *Staff network*: Main network with all resources
  - *Student network*: Network with main resources
  - *SCADA network*: Closed with no user access
  - *Extra network*: For special experiments
- Fiber communication lines
  - Provide “unlimited” bandwidth
  - Avoid EMC problems
- Main fiber cross-field with eight 48-port fiber switches
- End points with 1 Gbit 4-port fiber-to-PDS switches and raw fibers
  - 5 fiber pairs + 4 switches in each of 21 LabCell Boards
  - 1 fiber pair + 1 switches in each of ~50 wall sockets stations
  - In total 200 fibers + ~150 switches



## Modular Blade Server Infrastructure

- *Flexible computer facility for computational heavy experiments which can be accessed locally and remotely; consisting of two IBM Blade centers with in total 36 quad-core CPU's and 856 GB RAM memory*
- Application
  - Electricity market simulation
  - EV fleet management systems
  - Virtual power plant development and test
  - Power system analysis
  - Data collection and processing from field
  - Control room applications



## Electric Lab

Power and energy technologies  
for the intelligent grid

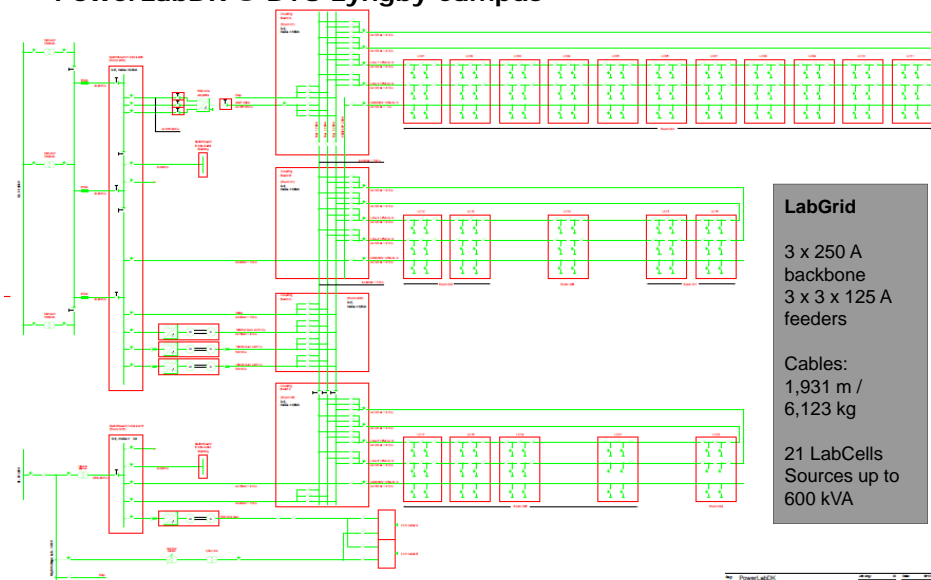


## LabCell Board Design



**LabCell Boards**  
 400 V  
 3 x 125 A feeders  
 RTU w. operator panel  
 5 x 63 A, 1 x 32 A,  
 7 x 10 A plugs  
 4 x 4 RJ45 1 Gbit networks  
 Integrated safety system  
 SCADA I/O's

## LabGrid PowerLabDK @ DTU Lyngby Campus



**LabGrid**  
 3 x 250 A  
 backbone  
 3 x 3 x 125 A  
 feeders  
  
 Cables:  
 1,931 m /  
 6,123 kg  
  
 21 LabCells  
 Sources up to  
 600 kVA

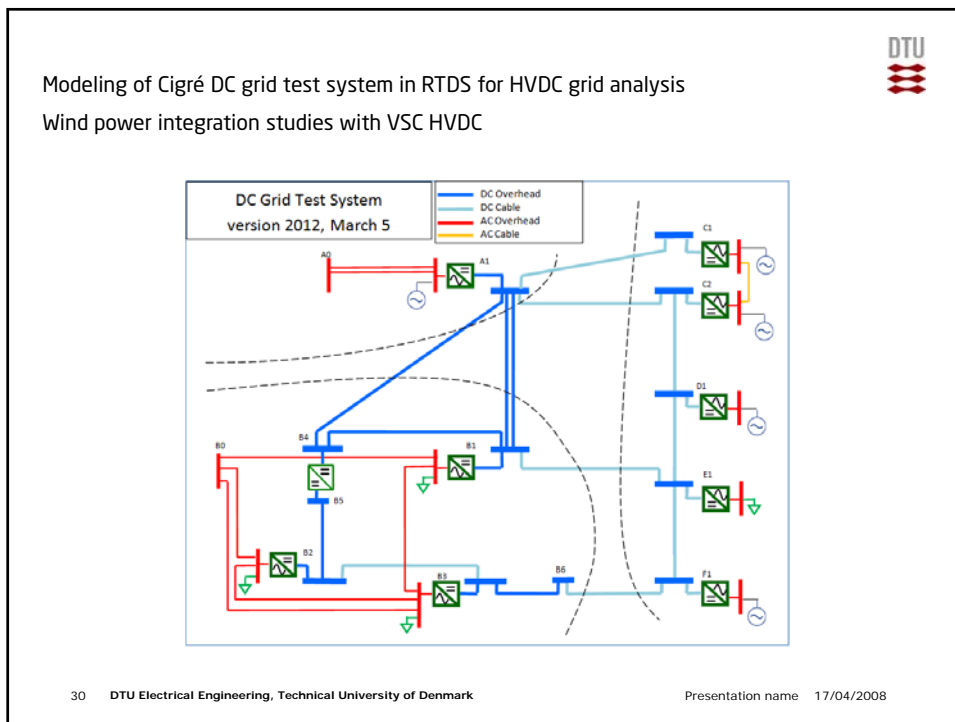
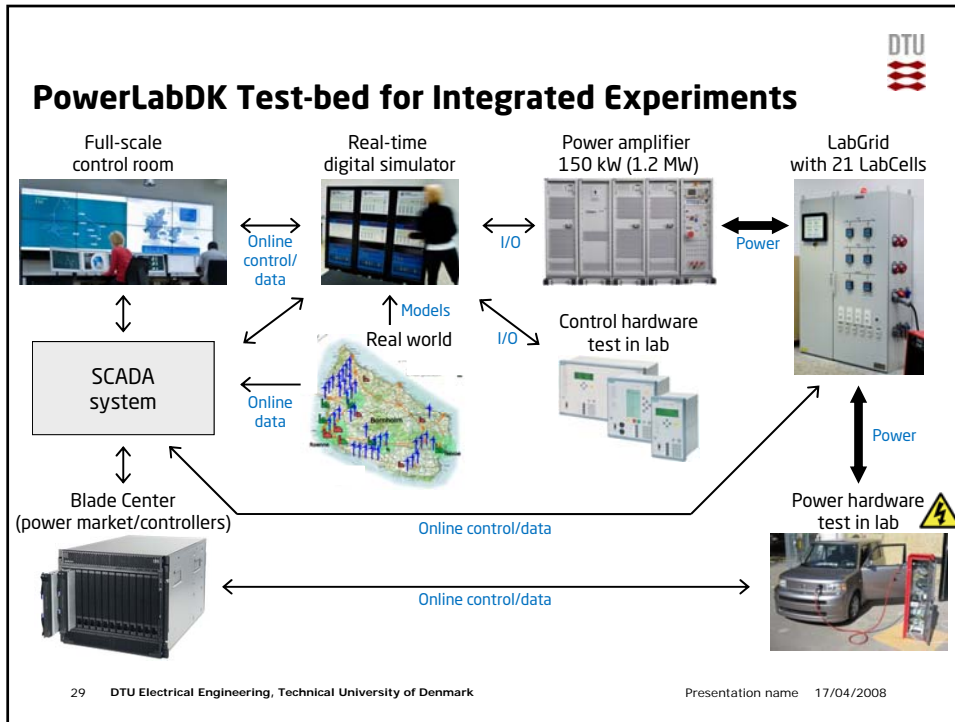


## 150 kW (1.2 MW) Four Quadrant Three Phase Analog Amplifier



- Manufacturer: Spitzenberger & Spies, Viechtach, Germany
- Frequency range: DC to 5 kHz (-3 dB), 50 kHz for small signal
- Slew rate:  $> 52 \text{ V}/\mu\text{s}$
- AC voltage ranges: 56 V, 135 V, 240 V, 270 V
- DC voltage ranges: 79 V, 191 V, 339 V, 382 V
- AC 24 hour output power: 150 kW
- AC 1 hour output power: 200 kW
- AC 5 min output power: 300 kW
- DC 24 hour output power: 50 kW per phase
- DC 1 hour output power: 75 kW per phase
- AC+DC 3 ms pulse output power: 400 kW per phase
- Power sink capability AC: 42 kW (1 hour - 90 kW)
- Power sink capability DC: 17 kW per phase
- Power sink capability AC+DC for 3 ms pulse: 80 kW per phase



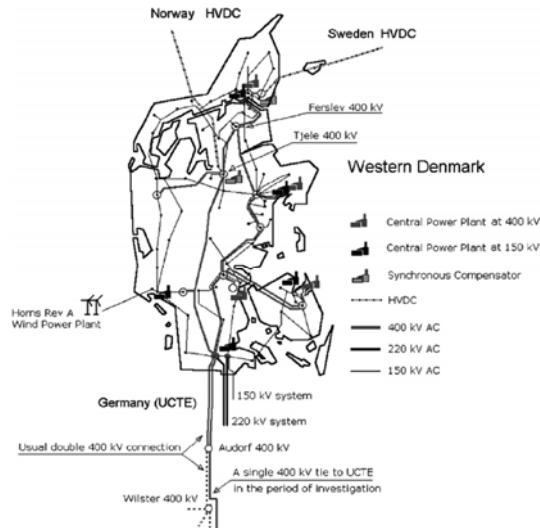




Modeling of the Western Danish Power System in RTDS and area control with high wind power penetration.



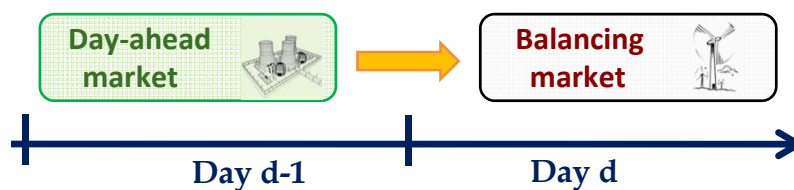
Time series of wind power production data will be very relevant.



## Electricity market design in the future renewable-based systems



• Today:



• In the renewable-based energy system in 2050...

- a) Need for a real-time market?
- b) Market coordination level?
- c) Incentives to invest in renewable generation?

## High Voltage, High Power and Student Labs

Components in interaction  
with complex energy systems



## SYSLAB and PowerFlexHouse

Intelligent distributed  
energy system in practice

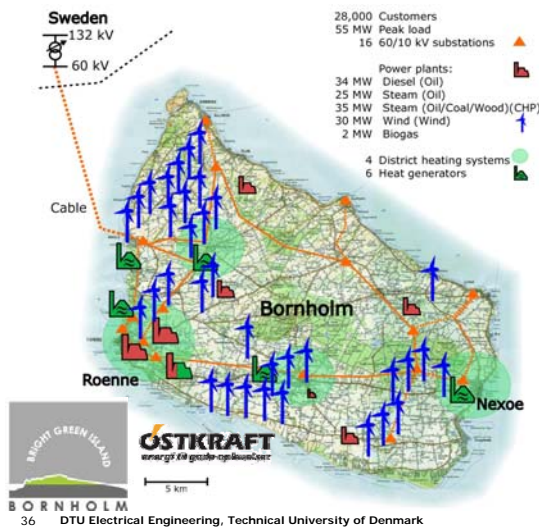


## SYSLAB @ Risø Campus



- A platform for DER research and testing
- Flexible experimental setup up
- Several RES units
- Embedded computing power and flexible communication
- Very flexible control possibilities

## Bornholm Full-Scale Laboratory – 1% of DK 33% Wind Power Penetration; 28,000 Customers



Energy strategy  
Political & public drive



Energy resources:

- Customers
- Wind power
- Biogas plant
- Combined heat and power
- District heating
- Solar power plants
- eMobility

Features:

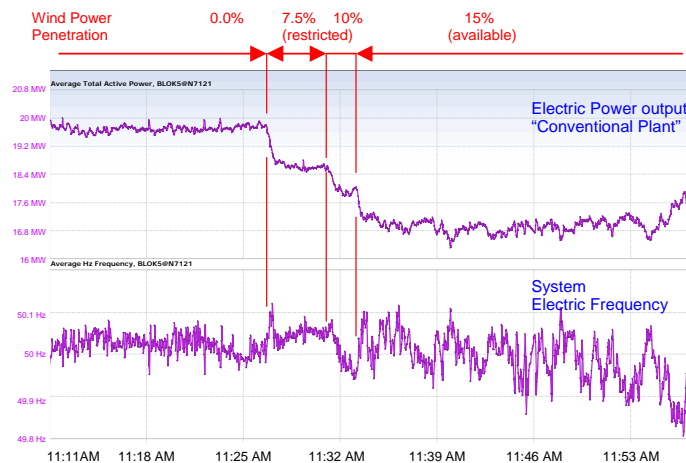
- Nord Pool market (DK2)
- Islanding capability

## Supervision and Measurements Systems covering Bornholm

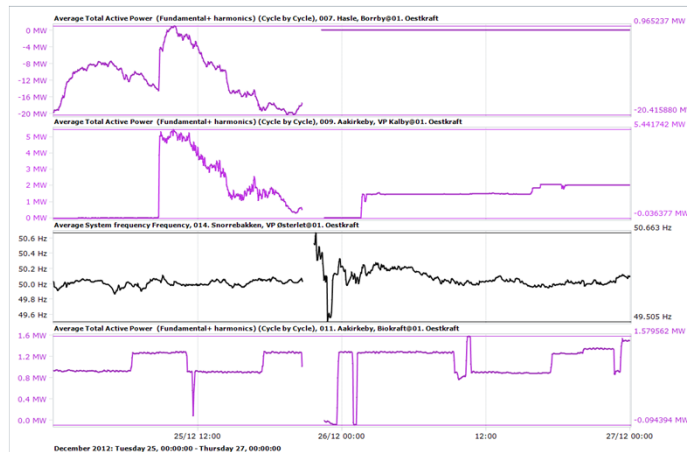
- **Control rooms with SCADA systems**
  - Operational ABB NM SCADA at Østkraft
  - Experimental ABB NM SCADA at DTU
  - Measurements collected with 1 s time resolution
  - 1,300 analogue signals 2,200 digital signals
- **ELSPEC G4430 BLACKBOX Power Quality Recorders**
  - All network parameters with up to 1,024/cycle resolution
  - 10 units in the grid + 7 units in the power plant
- **Phasor measurement units (PMU's)**
  - Voltage and current RMS + phase with 20 ms time resolution
  - Extremely accurate time stamping
- **Interval meters at customers**
  - Advanced 5 min interval meters
- **Forecasting systems**
  - Wind power generation, PV generation, electricity demand, heat demand



## Bornholm Island Operation 17 September 2009




## Bornholm Event December 25, 2012 1 ms Resolution Data



## Energinet.dk rammeaftale om udnyttelse af PowerLabDK

- Overordnede mål er at fastlægge rammerne for fremtidige samarbejde om udnyttelse af PowerLabDK's faciliteter
- Årlig ramme på 650-700.000 kr
  - Dækker brug af udstyr og lønninger
  - Der kan aftales yderligere aktiviteter
- Der aftales løbende årsplaner
- NDA for udveksling af data er indeholdt
- Årsplan 2013
  1. Opsætning af RTDS/SCADA/kontrolrum simuleringsplatform
  2. Implementering af modelnet
  3. RTDS-simulering med DER, fx PV og aktiv kontrol (der træffes nærmere aftale om dette)
  4. Plan for kommende års aktiviteter og analyser

**PowerLabDK**  - read more at [www.powerlab.dk](http://www.powerlab.dk)



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