Smart Grid Research in a Danish Perspective

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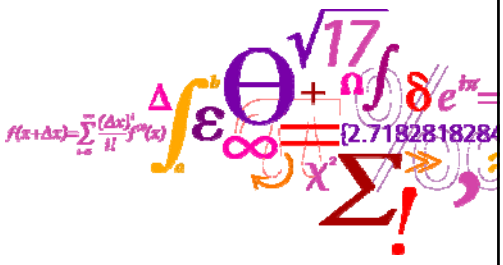
Department of Electrical Engineering

Fukuoka, Japan
10 December 2012



DTU Electrical Engineering
Department of Electrical Engineering

Smart Grids in Denmark

- Transformation towards a sustainable energy system is of outmost importance for society
  - Climate, Security of supply, Green growth
  - DK: Wind doubles to 50% in 2020; 100% RES in 2050 (ref: DK Government)

- DK: Electricity expected to doubles to ~70% of the total energy system (ref: DK Climate Commission) New technology and development of a Smart Grid is a prerequisite for efficient integration of high share of renewable energy

- Situation in Denmark
  - Wind power generation equals 26% of demand (2011)
  - The EU country with the highest share of the export within energy technology
  - 22% of EU's Smart Grid R&D projects takes place in Denmark (ref: EU)
  - National smart grid network established and national smart grid strategy to be launched

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

Selected National and International Collaboration Partners

- ***Academic partners:***

(CH) (NL) (CN) (DK) (FI) (US) (UK) (US) (HK) (SE) (SE)

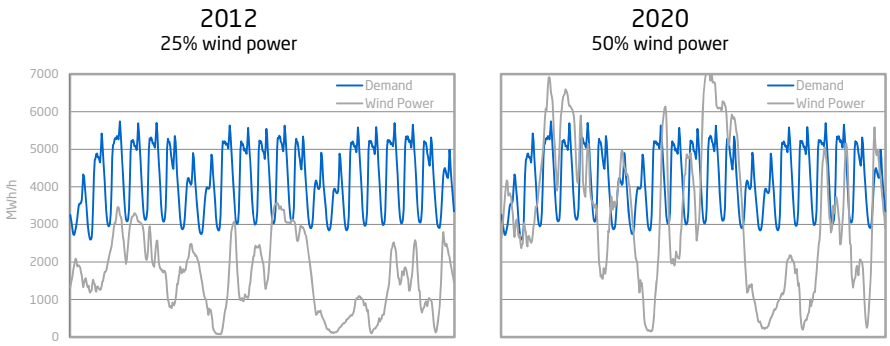
- ***Commercial and industrial partners:***

(DK) (DK) (DK) (BE) (DK) (UK) (CH) (DK) (US) (DK) (DK) (DE) (DK) (DK) + SME's

- ***International networks:***

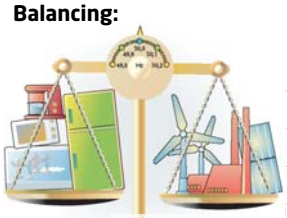
(EU) (EU) (Global)

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

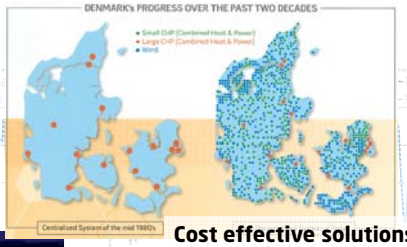


Some Main Research Challenges (and The Danish Wind Power Case)

Balancing:



Changed Generation Landscape:



Stability and Reliability:

Cost effective solutions:

Research Objective and Fields

Development of a reliable, cost effective and environmentally friendly electric power and energy system based on renewable energy sources

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

PowerLabDK

Comprehensive Experimental Facilities for Electric Power and Energy

Flexible multi-purpose laboratories

Lyngby & Ballerup Campus

Large-scale power system (1:10)

Risø Campus

Full-scale Realistic Power System

27,000 Customers
33% Wind Power
50% Renewable Energy
Islanding capability

Bornholm Power System

- Industrial stakeholders:
  ABB, nkt cables, DONG energy, SIEMENS, VATTENFALL, ENERGINET.DK, Vestas, IBM
- National support:
  GREEN LABS DK, EUDP
- Investment: 18 M€
  Hereof industrial funds: ~4 M€


PowerLabDK
Electric Lab
Power and energy technologies
for the intelligent grid
LabGrid
21 LabCells
Sources up to
600 kVA
3 x 250 A
backbone
3 x 3 x 125 A
feeders
Cables:
1,931 m /
6,123 kg
182
183
www.powerlab.dk
DTU Technical University of Denmark
INGENIØR HØJSKOLEN KØBENHAVN
ØSTKRAFT
energi til gode oplevelser


PowerLabDK
Intelligent Control Lab
Power system simulation, control
and supervision
RTDS
Real-Time Digital Simulator
www.powerlab.dk
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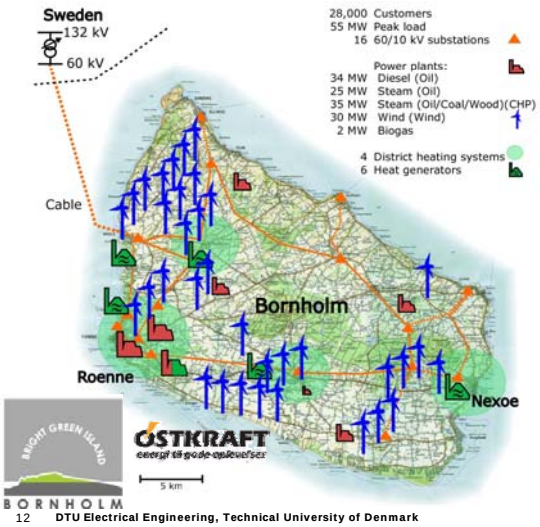
energi til gode oplevelser

SYSLAB at 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



Local Energy Strategy
Political & public drive

BORNHOLM.DK
BRIGHT GREEN ISLAND

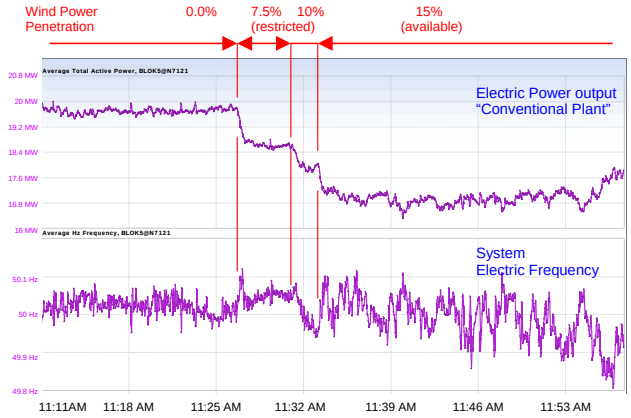
Energy resources:

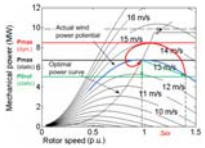
- *Wind power*
- *Biogas plant*
- *Combined heat and power*
- *District heating*
- *Solar power*
- *eMobility*

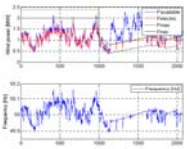
Features:

- *Nord Pool market (DK2)*
- *Islanding capability*

Bornholm Islanding Experiment



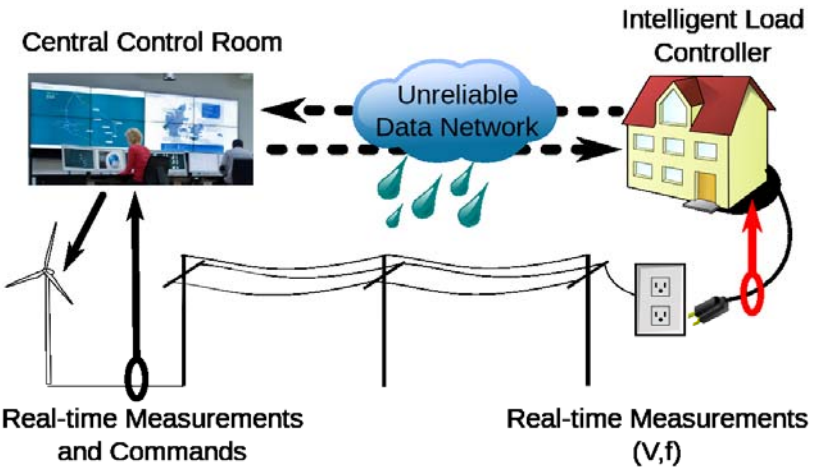




Vestas

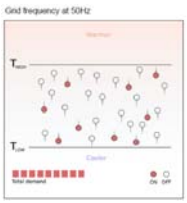
Refs: *9th International Workshop on Large-Scale Integration of Wind Power*, 2011
Patent No. US20120161444, 2011

Autonomous V- and f-services from demand



System Reserves Provided by Frequency Responsive Electricity Demand

- Field test w. 200 residential, commercial and industrial demand units

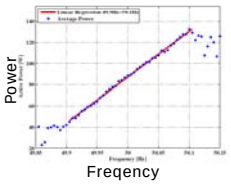


$$T_{high} = T_{high}^{normal} - kf\,(f - f_0)$$

$$T_{low} = T_{low}^{normal} - kf\,(f - f_0)$$

Field test at Bornholm

- Results
  - Demand can with maintained energy service deliver reserves which today are delivered by large power plants
  - Pay pack time = 1-2½ year w/ 1 kW unit
  - Ease of implementation, supporting commercialization

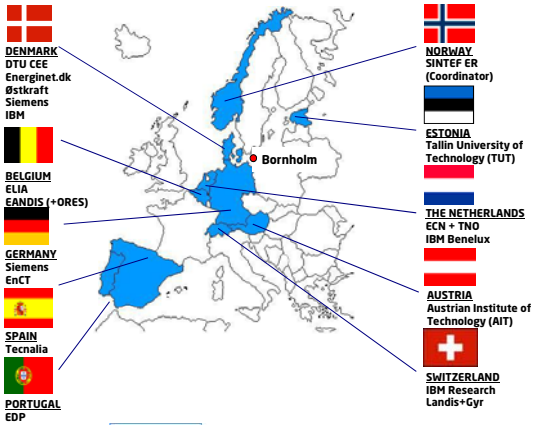


Refs: *IEEE Transactions on Power Systems*, August 2011.
IET Generation Transmission and Distribution, August 2009.

EcoGrid EU

Large-scale demonstration of the future intelligent distribution system

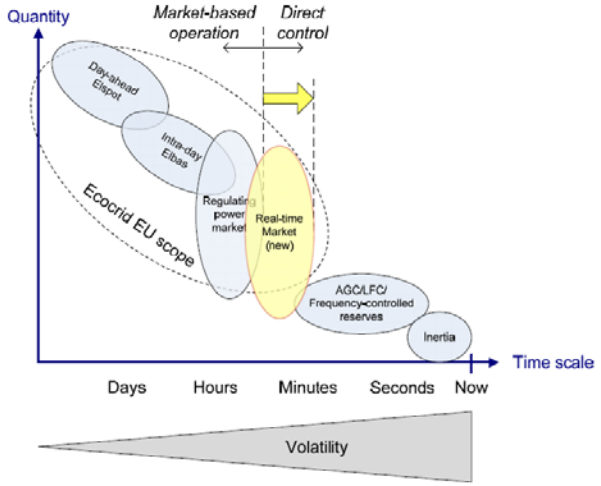
- Integrated research and large-scale demonstration of Smart Grids
- ~2,000 active customers
- EU fast-track to Smart Grids
- 2011-14
- 21 million Euro



Awarded *Best Sustainable IT-project 2012* by Arnold Schwarzenegger et. al

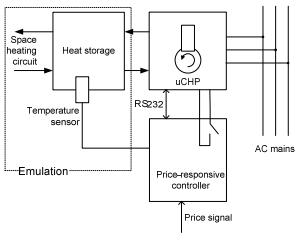
Extention of the Electricity Market Solutions

Smaller Participants and Shorter Time Constants



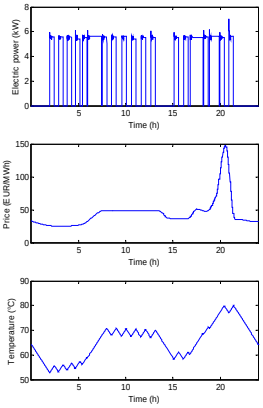
Control-by-price Concept with 5 min Real-time Market

Lab. setup with micro CHP:



Elec. gen,	5 kW
Heat gen.	10.5 kW
Heat demand (constant)	5.25 kW
Storage	750 liter
Min. temp.	50 ° C
Max. temp.	80 ° C

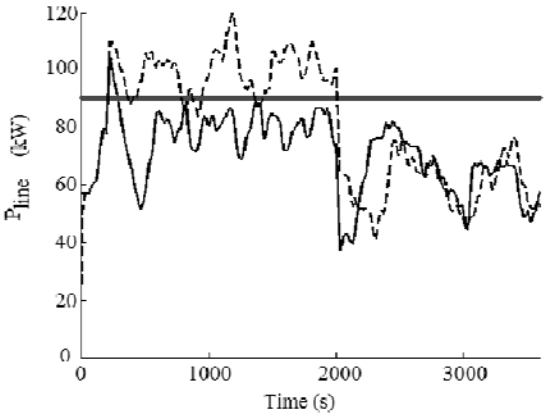
Measuements:

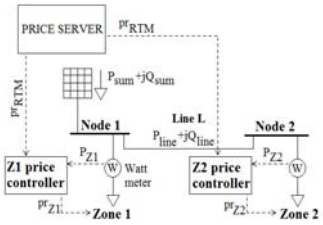


Increased income = **7.3%** wo/ comfort changes (and very simple algorithm)

Ref: *IEEE Transaction on SmartGrids*, 2011.

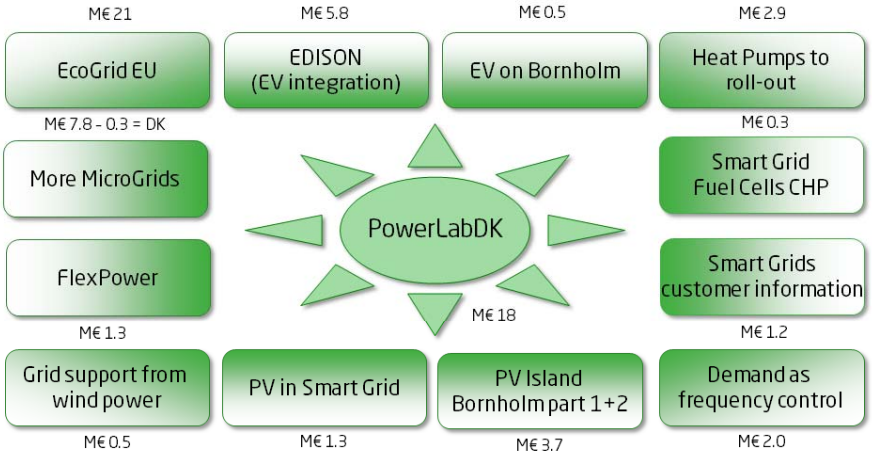
Congestion Management in Distribution Grid by 5 min Dynamic Grid Tariffs





Ref: *IEEE ISGT Europe*, 2011.

Smart Grid related Activities at Bornholm

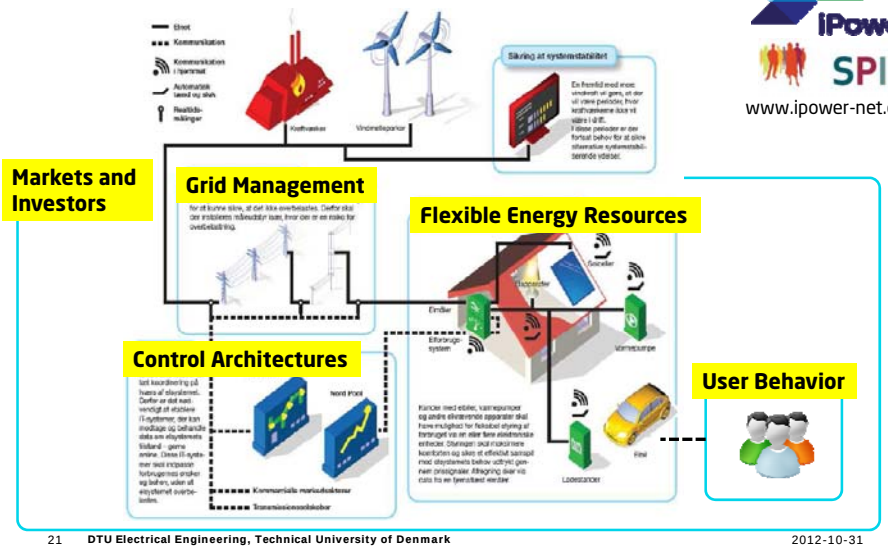


Some M€ 40 invested in Smart Grid related technologies at Bornholm.

iPower - Strategic Platform for Innovation and Research

30+ partners, 5 years

www.ipower-net.dk



IEEE ISGT 2013 OCTOBER 6-9 COPENHAGEN

4th IEEE PES Innovate Smart Grid Technologies Europe 2013

Copenhagen, Denmark
6-9 October 2013

Hosted by Technical University of Denmark

Bringing industry and academia together

More information:
www.ieee-isgt-2013.eu

IEEE ISGT 2013 OCTOBER 6-9 COPENHAGEN

4th IEEE PES Innovate Smart Grid Technologies Europe 2013

Bornholm power system
(2,000 smart customers and 50% RE)

Smart Grid control room
(wind; state-estimation; VPP's)

EV fleet operation
(e.g. Better Place)

PowerLabDK smart grid labs
(2,000 m² lab; field lab at Risø Campus)

Off-shore wind farms

Den grønne industrikommune Kalundborg

Smart city Kalundborg

IEEE

IEEE PES Power & Energy Society™

Thank you!

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