Achieving 20% wind power in the Danish electricity system and moving on to 50%

Integración de Centrales Eólicas en Sistemas Eléctricos de Potencia

Mexico City, 3 November 2011

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Agenda

• Introduction to Energinet.dk
• Operating the Danish Electricity System with 20% wind power
• Preparing for 50% wind power 2020 and a fossil free energy system 2050
• Conclusions
Energinet.dk

• National Transmission System Operator for electricity and gas in Denmark (TSO)

• Independent public enterprise under the Ministry of Climate, Energy and Building
  • Own Supervisory Board appointed by the Minister

• Approx. 590 employees, Headquarter in Erritsø - Jutland

• Owns and operates the transmission systems for electricity and gas
Energinet.dk - Facts

• Co-owner of
  • the Nordic power exchange Nord Pool Spot
  • the Danish gas exchange Nord Pool Gas
  • the European Market Coupling Company EMCC

• Owns and operates underground natural gas storage facility Lille Torup

• Annual turnover: DKK 8-9 billion ~ MXN 20-22 billion
  • Consumers contribute to activities via tariffs on their electricity and gas bills
  • The finances of Energinet.dk must break even, i.e. a non-profit company
  • The company cannot be sold
Core Tasks for Energinet.dk

• Ensure short- and long-term security of supply for electricity and gas
• Ensure well-functioning markets for electricity and gas
• Ensure well-functioning emergency preparedness of the energy sector
• Own, operate and maintain the gas transmission grid
• Own, operate, maintain and enlarge the 400 kilovolt and parts of the 150/132 kilovolt electricity transmission grid
Location of Energinet.dk
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Danish energy policy:

- 1.300 MW of new wind-power capacity ~ +40%!

EU 20-20-20 target – 30% renewables in DK:
- Power system may have to handle 50% wind power!

New Danish government – September 2011:
- 2020: 50% wind power in electricity system
- 2035: Fossil free electricity and heating systems
- 2050: Fossil free energy system
Power balance Jan. 2011

Two synchronous areas

West:

- Consumption: 1400 - 3700 MW
- Primary power stations: 3400 MW
- Local CHP plants: 1860 MW
- Wind turbines: 2840 MW

4700 MW

East:

- Consumption: 900 - 2700 MW
- Primary power stations: 3800 MW
- Local CHP plants: 640 MW
- Wind turbines: 960 MW

1600 MW
Wind power already exceeds hourly demand today!

Wind Energy coverage in DK West: 28%
Wind power balanced in a large market area

- Strong transmission grids and interconnectors
- Coherent electricity markets
Wind power balanced in a flexible generation system

• Coal fired power plants:
  • Required to operate down to 35% of rated power
  • Some are capable to operate down to 10%

• Combined heat and power plants:
  • Heat accumulators decouple electricity and heat demand
  • Electric boilers give flexible demand

• Wind farms:
  • Grid codes ensure capability to support system
Even wind power can contribute to system balancing!
The electricity market

The four market places in Denmark:

- Spot (day-ahead)
- Intraday
- Regulating power
- Reserves
The phases of the daily power market

- **Bids to Nord Pool’s spot market**
  - Monday 00:00
  - 12:00
  - 13:00

- **Prices and volumes published by Nord Pool**
  - 13:00

- **Operational schedule send to Energinet.dk**
  - 15:00

- **Bids to the intraday market**

- **Bids to the regulating market**

- **TSO maintains physical balance by means of regulating power**

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**Trade**

**Operation**

**Settlement**
The regulating market
- bridging the financial and physical system

- Regulating power bids from **all** Nordic countries listed in price order - NOISE
- Up and down regulation bids are activated by TSOs in accordance with price list
- Marginal bid in one hour determines the price for all suppliers

- Energinet.dk pays for reserve capacity to ensure availability
Prices in the regulating market

EUR/MWh

- Spot price
- Up-regulation price
- Down-regulation price

Jan-03 to Okt-07
System Operation

Security of supply is the key focus area for System Operation in any energy system - conventional or sustainable

3 major preconditions for Security of Supply:

1. Availability of power to cover demand for day-a-head plans

2. Sufficient availability of resources to cover system imbalances in the operational hour

3. Advanced systems for balance management and grid security calculation
Balancing and Grid security

Energinet.dk has developed two essential IT systems to manage the large amount of sustainable generation:

• Operational Planning System:
  - providing information on imbalances in the coming hours on the basis of forecasts, up-dated generation plans, on-line measurements and DGM input

• Distributed Generation Management System (DGM):
  - providing the basis for forecasting renewable generation and grid security calculations (load flow)
Operational Planning System

Providing on-line up-dated forecast for system imbalances:
Operational Planning System

• Imbalance = Consumption - Wind Power - Local CHP
  - Primary Power Stations +/- Exchange

• Consumption, Wind Power and Local CHP are based on regularly updated forecasts

• Primary Power Stations and Exchange are scheduled by the market players and continuously updated on-line

• The dispatcher buys and sells regulating power from the regulating market to bring the imbalance close to zero

• Remaining minor imbalances are balanced by automatic reserves
Distributed Generation Management System

- 6300 generators on 4600 ‘plants’
- 18 Balance Responsible Parties for Production (PBR)
- 4525 plants without individual schedules
- 75 plants with individual schedules
DGM in real time mode – generation forecast

Direction of data flow

Balancing area

Area 1
Substation 1

Area 2
Substation 2

Substation 3

PBR
A A A B A A A B A
DGM in offline mode - for grid security calculation

Forecast models

Area 1

Substation 1

Substation 2

Substation 3

Area 2

Direction of data flow
System Operation in a sustainable energy system
- a few essentials

• Flexibility of resources available for balancing
  • Coal fired power stations can operate from 10 – 100%
  • Strong interconnectors to neighbors for intra-day trading
  • The Nordic market for regulating power is efficient and large
  • Availability of local CHP units for regulating power provides flexibility in volume and time
  • Consumption – prevailing heat pumps and electric heating - efficient for down-regulation
  • Wind turbines will next year have access to market for regulating power

• High quality forecasting systems - Operational Planning System

• On-line systems for generation and grid security calculation - Distributed Generation a Management System
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Main challenges for the Danish electricity system

![Graph showing RES share in electricity system from 2010 to 2020, increasing from 20% to 50%]

- RES share in electricity system
- Security of supply
- Market function

- 2010: 20%
- 2020: 50%
- 2010: Security of supply
- 2020: Market function
Energinet.dk’s strong prioritisation for 2020

Production

50% Wind

Means and solutions

Robust transmission grid, strong interconnectors and market integration

Flexibility in demand and production – cooperation with the heat and transportation sector

Smart Grid for efficient control and market based regulation of the power system
Long term grid planning
- available sites for 4.6 GW offshore wind power
Interconnectors – planned and upcoming projects

**Skagerrak 4**
700 MW - HVDC
NO-DK1
HVDC - VSC

**COBRA**
700 MW - HVDC
NL-DK1
EC co-funding
HVDC - VSC

**Anholt 1+2**
400 MW
Wind farm offshore

**Kriegers Flak**
600 MW Wind farm offshore
600 MW – HVDC
HVDC - VSC
DE-DK2
EC co-funding
Main Drivers for grid development– ENTSO-E TYNDP
Market coupling
- pilot project in North West Europe

Goal:
- Optimal utilization of exchange capacity
- One price calculation for the whole area

First step in November 2010:
- Interrim Tight Volume Coupling
- CWE-Nordic Countries

Second step end 2012:
- Permanent price coupling
- North West Europe
Coherent and flexible energy systems

50% of electricity demand

- Electric vehicles
- Heat pumps
- Electric boilers
- Gas & Oil
- Other sectors

Transportation

District Heating

Electricity
The energy system – shift of paradigm

Present Future

Energy fuel of the future

Energy fuel of today

Share of electricity today

Share of electricity in the future

Grid for electricity, heat and gas

Grid for electricity, heat and gas

Energy conversion

Energy conversion

Transport Heat Cooling Production Services Lightening

Transport Heat Cooling Production Services Lightening

Coal & Oil N-gas Wind Biomass B-gas Solar

Coal & Oil N-gas B-gas Solar Biomass Wind

Production

Services

Lightening

Share of electricity in the future

Share of electricity today

Energy fuel of today

Energy fuel of the future

Present Future
Integration of wind power
– synergy between gas and electricity

- Substantial storage capacity in the gas sector at low costs
- Competitive peak-load capacity from RE-Gas conversion- Turbines, FC or CC
- Optimal use of bio resources
Smart Grid is the future

Smart Grid – puzzle to the future RES electricity system
Smart Grid – what is missing in Denmark?

- Grid
- Communication

- Operation and SCADA
- Market
- Production
- Transmission
- Distribution
- Service provider
- Costumer

A question mark indicates the missing component.
Cell Controller – world class R&D

Pilot Cell:
Holsted 60 kV Net

- Installed CHP: 37 MW
- Installed Wind power: 39 MW
- Peak load: 61 MW
- 150/60 kV Trans: 100 MVA
EDISON – Large scale EV project in Denmark

Electric vehicles in a Distributed and Integrated market using Sustainable energy and Open Networks
Bornholm – a Unique Test Site

- Demonstration in a “real” system with 50 % RES
- High variety of low carbon energy sources
- Several active demand & stationary storage options
- Interconnected with the Nordic power Market
- Operated by the local municipally owned DSO, Østkraft
- Eligible RD&D infrastructure & full scale test laboratory
- Strong political commitment & public support
Conclusions

Efficient integration of large-scale wind power through:

- **A strong international transmission grid**
  - to trade and balance in a wide geographical area
- **Efficient international electricity markets**
  - with clear price signals and trading close to real-time
- **Coherent energy systems**
  - to increase flexibility and economic efficiency and reduce environmental impact – electricity, heat and transportation
  - cooperation between gas and electricity
- **High flexibility in generation and demand**
  - with technical connection requirements for all resources – Grid Codes
- **A revised power system control architecture**
  - for active control of distributed resources - SmartGrids
Unrivalled expertise for your power system

- Energy system planning and development
- Electricity market design and development
- Grid operation and development
- Grid connection and integration of wind power

Thank you for your attention!

Power right now: http://energinet.dk/Flash/Forside/UK/index.html
Extra slides
Onshore wind power

Who builds, owns, operates and pays?

Feed in tariff = Market price + Fixed subsidy  (kr/kWh)
Offshore wind power

Who builds, owns, operates and pays?

Wind farm owner → TSO

- Offshore platform
- Offshore cable
- Onshore cable
- Onshore substation
- 400/220/150/132 kV grid

Public tender for building and operating OWF (kr/kWh)

Energinet.dk also carries through the EIA for the OWF
Regulatory regime for the grids of regional transmission companies and distribution companies

- Regional transmission companies
  - Price cap pricing
  - Necessary investment costs for grid reinforcement increase the price cap
  - The regional transmission grid is placed at the disposal of the TSO (Energinet.dk) – hence an increase in the price cap is added to the TSO's grid tariff

- Distribution companies
  - Necessary investment costs related to RES are reimbursed by the TSO
  - These costs are included in Energinet.dk’s PSO tariff

- Result:
  - All necessary costs for connecting a wind farm to the grid are divided between all Danish electricity consumers
Electricity price for households

<table>
<thead>
<tr>
<th>Component</th>
<th>Danish Kroner</th>
<th>Euro</th>
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<tbody>
<tr>
<td>Market price + tariffs</td>
<td>0,86</td>
<td>0,12</td>
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<tr>
<td>TAX</td>
<td>0,72</td>
<td>0,10</td>
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<tr>
<td>VAT 25%</td>
<td>0,40</td>
<td>0,05</td>
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<tr>
<td><strong>Total price</strong></td>
<td><strong>1,98</strong></td>
<td><strong>0,27</strong></td>
</tr>
</tbody>
</table>
Experiences with grid connection of several offshore wind farms

• Five grid connections for large offshore parks in Denmark – established or under construction
  • Horns Rev 1 – 2002, 150 kV, 160 MW ✓
  • Nysted 1 – 2003, 132 kV, 160 MW ✓
  • Horns Rev 2 – 2009, 150 kV, 215 MW ✓
  • Rødsand 2 – 2010, 132 kV, 215 MW ✓
  • Anholt - 2014, 220 kV, 400 MW
  • Kriegers Flak - 2016, 400 kV, 600 MW
Update on Energy demand growth

Demand for electricity

GWh

Electricity Kettles
Electrical Vehicles
Heat Pumps
Classical consumption

Spot-market
- demand and supply meet day-ahead

=> 24 hourly spot prices
The intraday market
- continuous trading up to one hour prior to delivery

Day-ahead market

Intraday
- up to 36 hours ahead

Double auction
day-ahead market

Continuous trading
until 1 hour before delivery

TSOs real time market

Regulating power market
Common Nordic NOIS-list
Cell Controller Architecture

- Layered control hierarchy using distributed agent technology and high speed fiber network
- Each agent consists either of an industry CPU, a high-end RTU or an intelligent meter

Virtual Power Plant
Wind turbines, CHP units and a little extra