European Experience on Integration of Wind Power with the Grid

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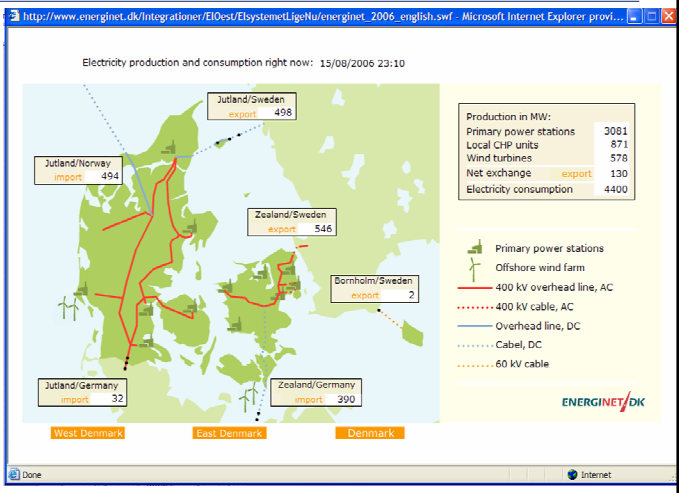
Agenda

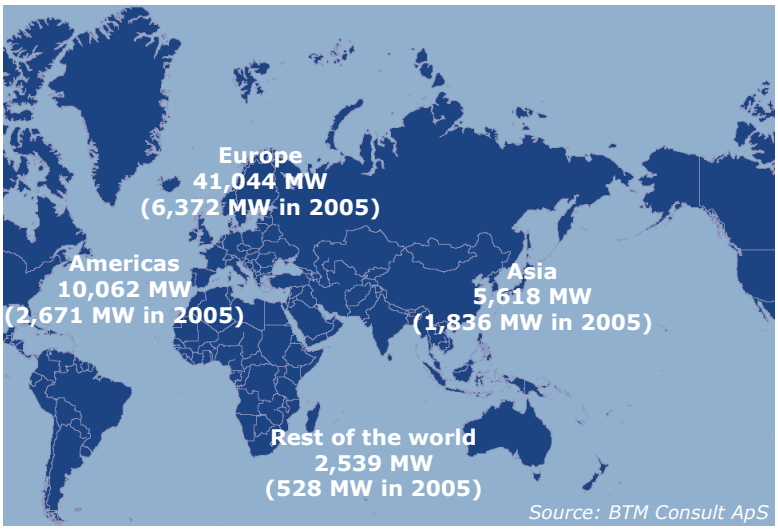
- Wind turbines penetration in Denmark and Germany
- Development of the wind turbine industry
- History – turbine technology
- Today – turbine technology
- Power Quality
- Conclusion

Snapshot from yesterday in Denmark

- 4400 MW consumption
- 578 MW wind
- 871 MW CHP
- Wind covers 13%
- Wind and CHP covers 33%

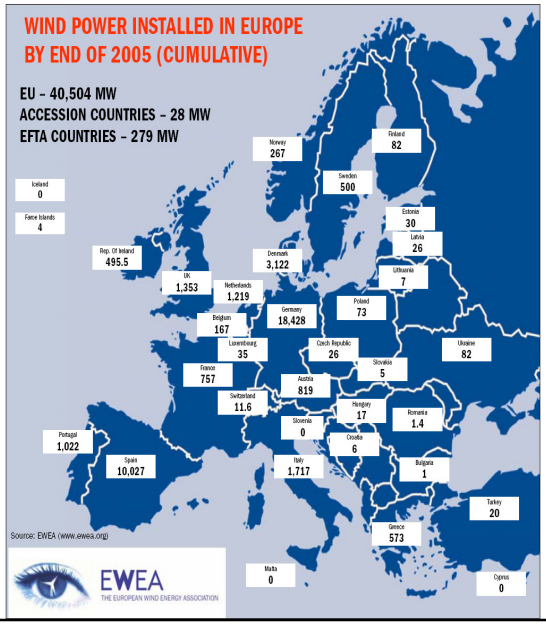


Accumulated installed capacity 2005



- Global installed capacity in 2005: 11,407 MW
- Global accumulated installed capacity 2005: 59,264 MW

Wind Power in Europe 2005



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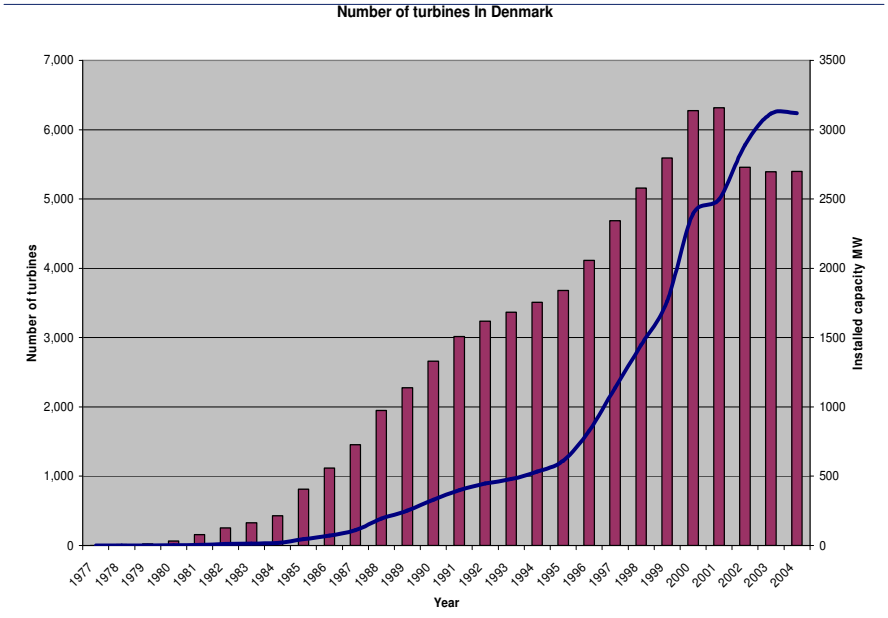
Turbines in Denmark



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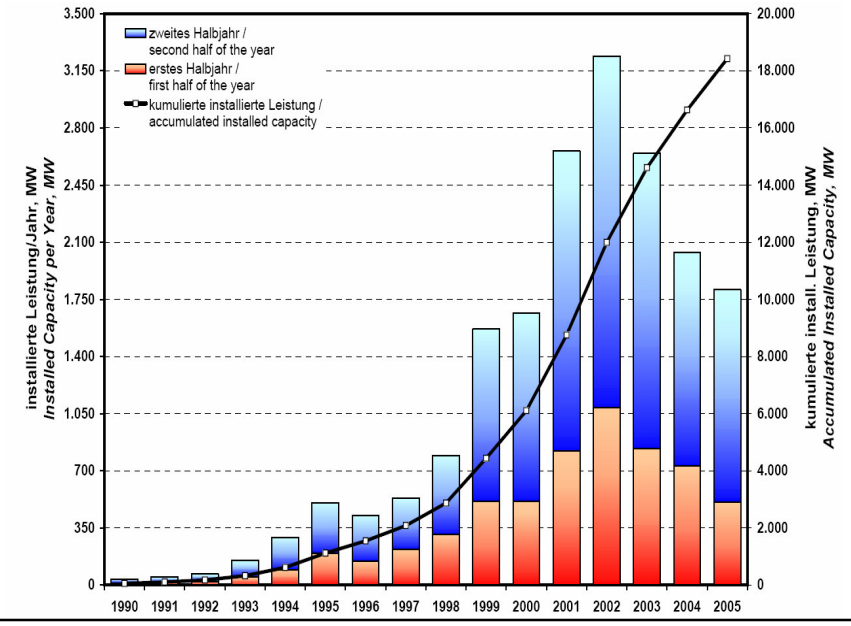
Turbines in Germany



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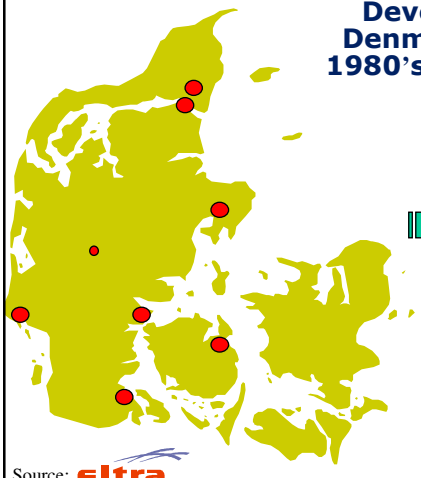
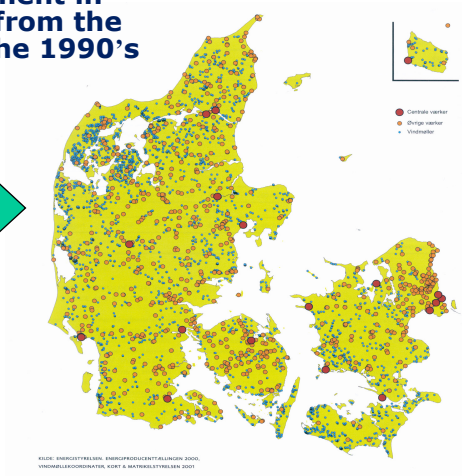
Power production in Denmark

Central generation

Decentral generation

Development in Denmark from the 1980's to the 1990's





Source: eltra

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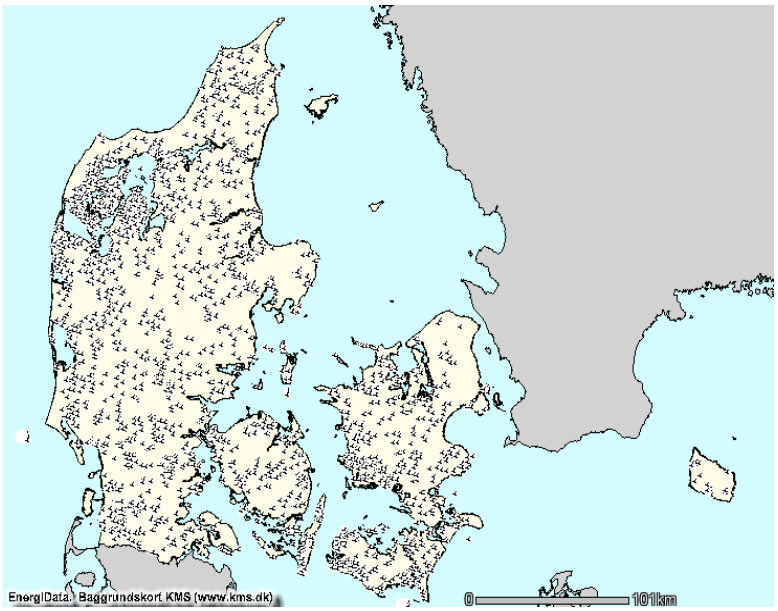
Wind Turbines in Denmark



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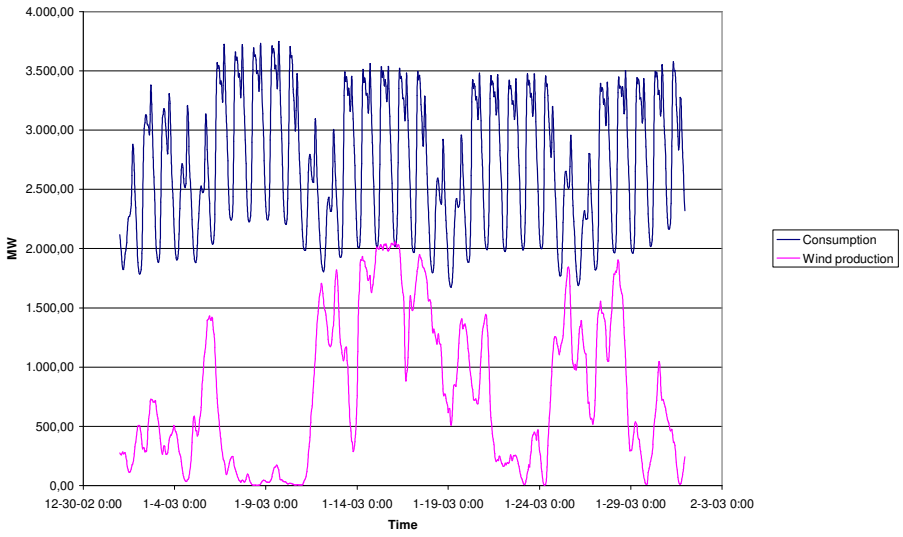
Wind in west Denmark
Penetration January 2003



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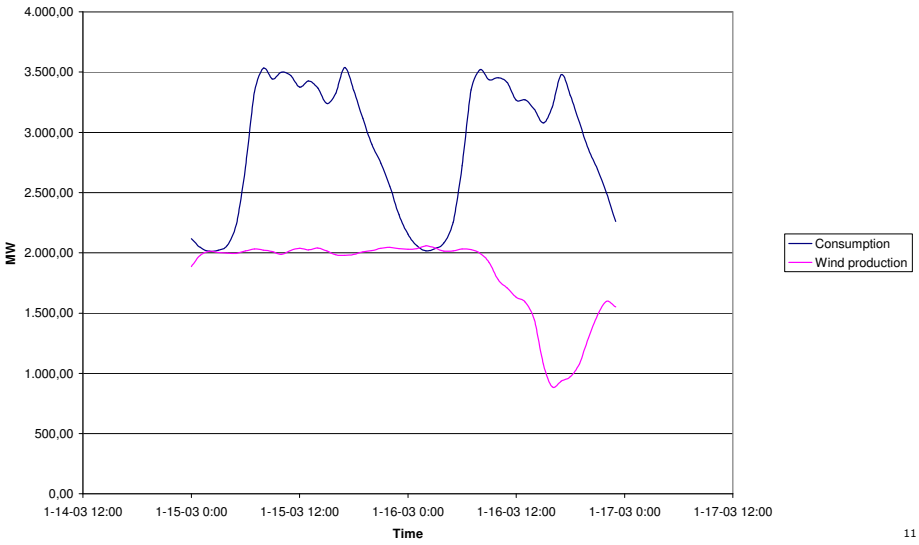
Wind in west Denmark Penetration 15-17/1-2003



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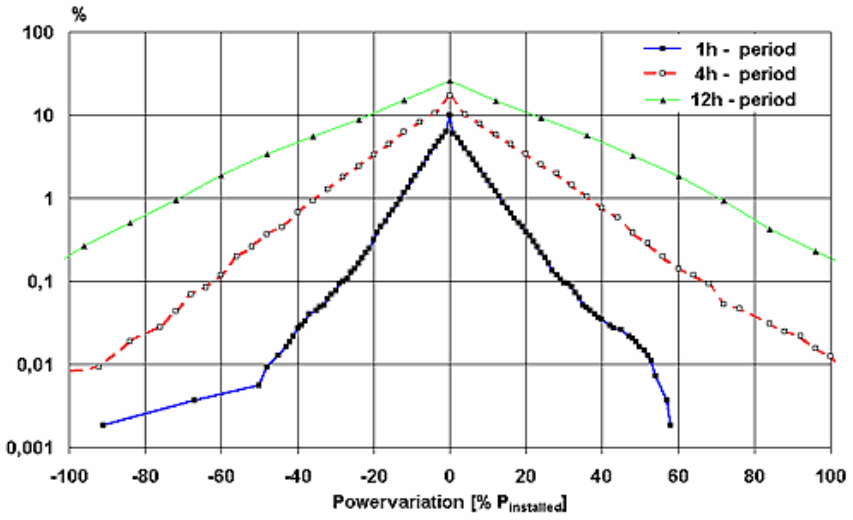
Wind in Germany - Individual turbines



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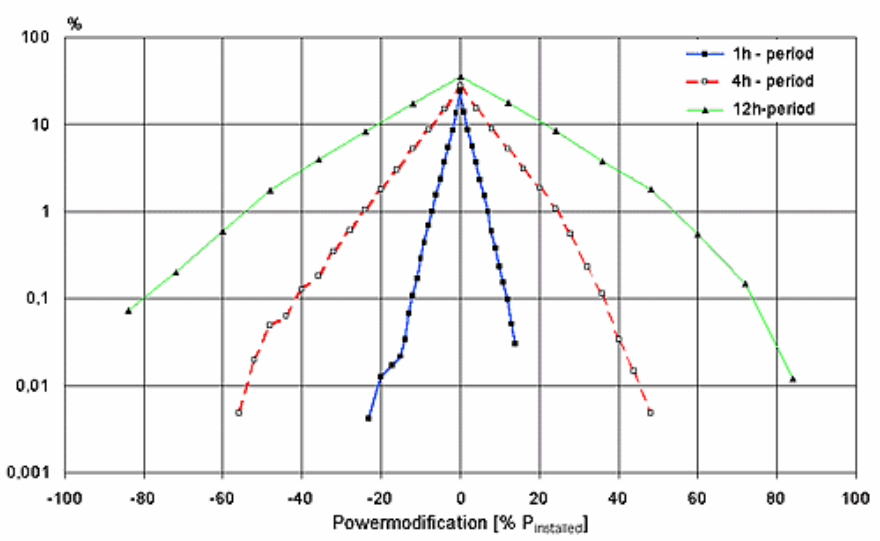
Wind in Germany, more than 1500 turbines



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Development of wind turbines

Product/ Rotor diameter (m)	V15	V17	V19	V20	V25	V27	V39	V44	V47	V52	V66	V80	V82	V90	V90	V100	V120
Year of installation	1981	1984	1986	1987	1988	1989	1991	1995	1997	2000	1999	2001	2003	2004	2002	(2006)	(2009)
Capacity (kW)	55	75	90	100	200	225	500	600	660	850	1,750	1,800 2,000	1,650	1,800 2,000	3,000	2,750	4,500

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History – Grid requirements

Old requirements for grid connection

- Voltage increase maximum 1 % at PCC (DK)
- Typically grid minimum 20 times short circuit level compared with turbine rating
- Turbines mainly connected to distribution grid
- No requirements regarding flicker
- No requirements regarding harmonics
- No requirements regarding grid support

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History – Turbine technology

Turbine technology used

- Passive stall turbines
  - Induction generator, single or two speed version
  - Capacitors for power factor compensation
  - Thyristor used for generator cut-in
  - Disconnected if voltage and frequency was outside a specified range

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Today – Grid requirements

New requirements for grid connection

- Grid codes towards wind farms
  - Transmission connected wind farms
  - Requirement as on traditional power plants, depending on national requirements
    - Reactive power support
    - Active power support
    - Fault ride through

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Today – Turbine technology

Turbine technology used / 1

- Active stall turbines
  - Induction generator, single or two speed version
  - Capacitors for power factor compensation
  - Thyristor used for generator cut-in
  - Fault ride through options
  - Reactive power support with capacitor banks, Statcom, SVC etc. (substation or turbine)
  - Active power support

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Today – Turbine technology

Turbine technology used / 2

- Pitch regulated variable speed turbines
  - Converter controlled power factor compensation
  - Converter used for generator cut-in
  - Fault ride through options
  - Reactive power support
  - Active power support

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Today

Reactive power support

There are different options for placement of the compensation equipment for Reactive power support

- Compensation equipment in each turbine
  - Possibility to use the turbine standard equipment
  - Higher park losses and difficulties to transfer active power
- Compensation equipment at the wind farm sub station
  - Faster and easier to control, no problems with cable losses etc
- Compensation equipment at the needed point in the grid
  - Compensation where it is needed (at the consumers)
- Combination of the above solutions
  - Likely the best technical and cost optimum solution

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Power Quality

IEC 61400-21 – Power Quality from Wind turbines

Measured by a third part measurement institute

- Power peaks measurement
- Flicker measurement
- Harmonic measurement
- Cut-in measurement
- etc

From these measurement it is possible to calculate the maximum number of turbines on a grid without disturbing the grid.

Vestas have IEC 61400-21 Power Quality Reports on all our turbines

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Conclusion

- Wind Farm Grid connection point has moved from distribution connection to transmission connection, as the wind farms gets bigger
- Wind turbines has technical seen stepped up in technology used several times, from stall, pitch, and now variable speed
- Wind turbines is now/will be a part of the national electricity production and play a important role
- It is necessary/important to have a good and open dialog between all parties regarding grid connection requirements of wind turbines

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Thank you