

# European Experience on Integration of Wind Power with the Grid

By Michael Rasmussen, Product Manager  
Vestas Asia Pacific, Technical support



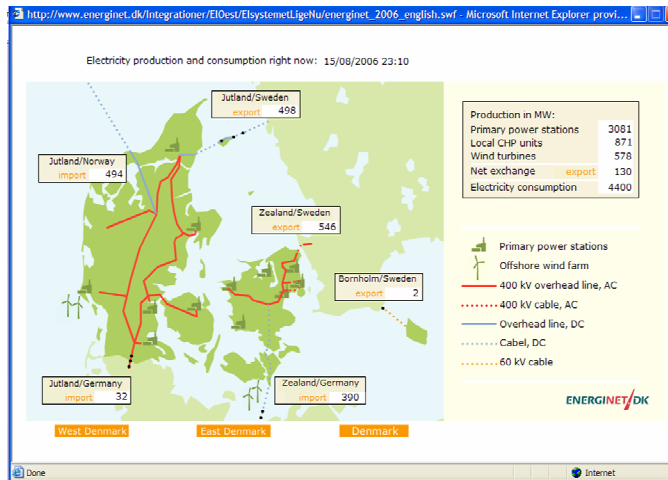
## Agenda

---

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

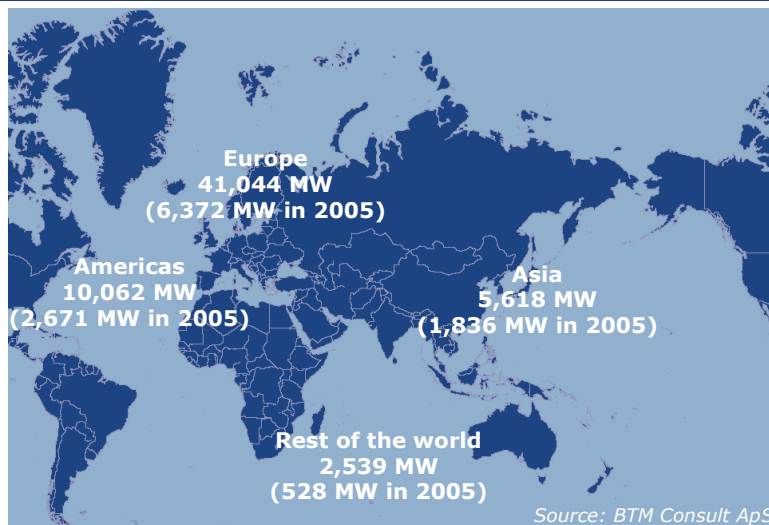
## Snapshot from yesterday in Denmark

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



3

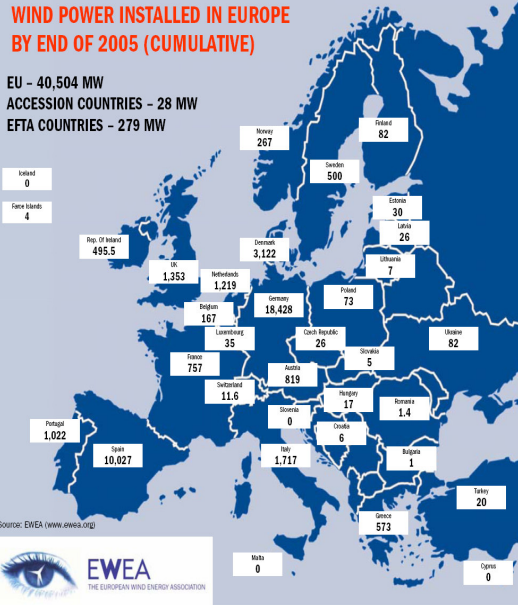
## Accumulated installed capacity 2005



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

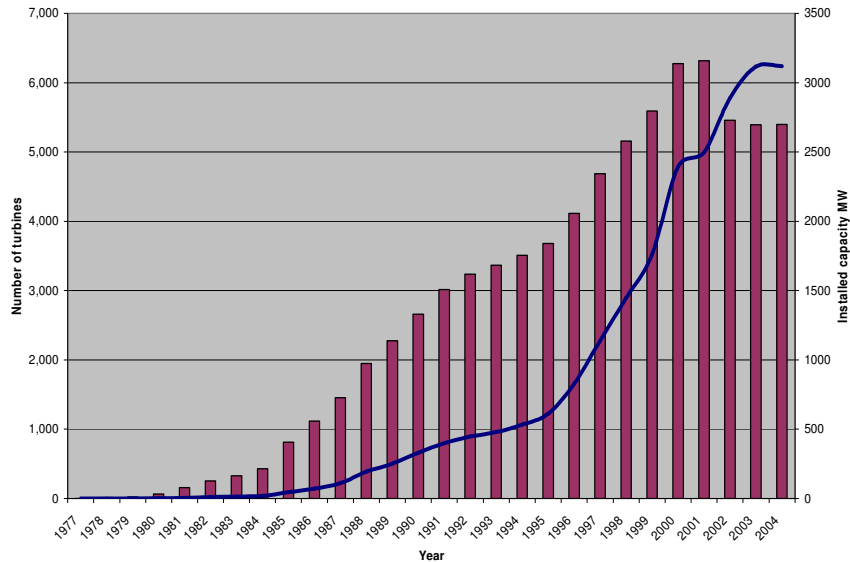
4

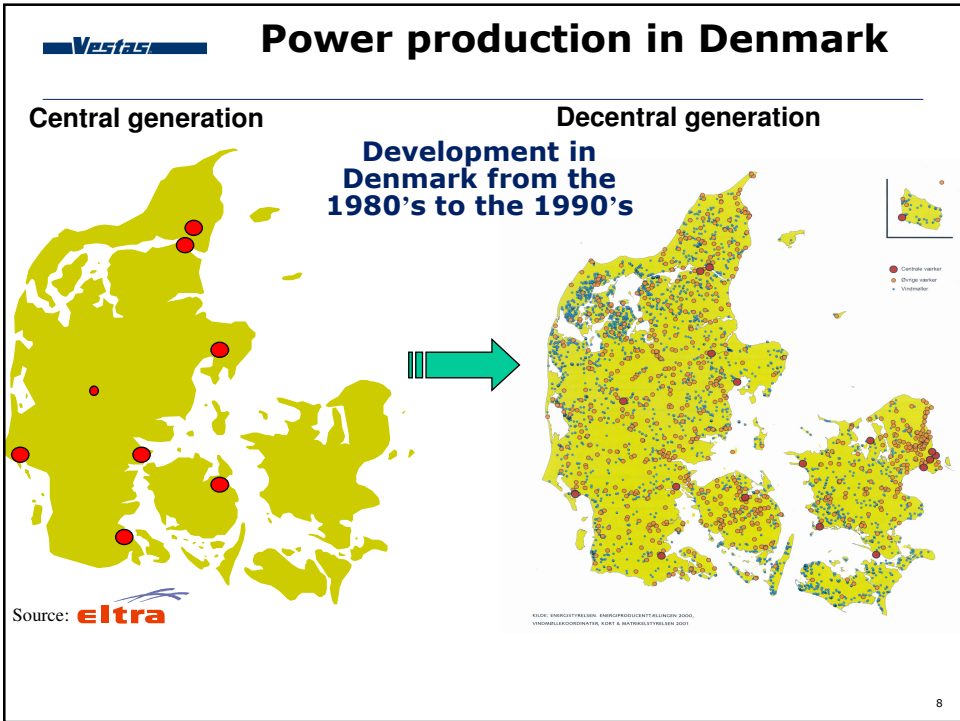
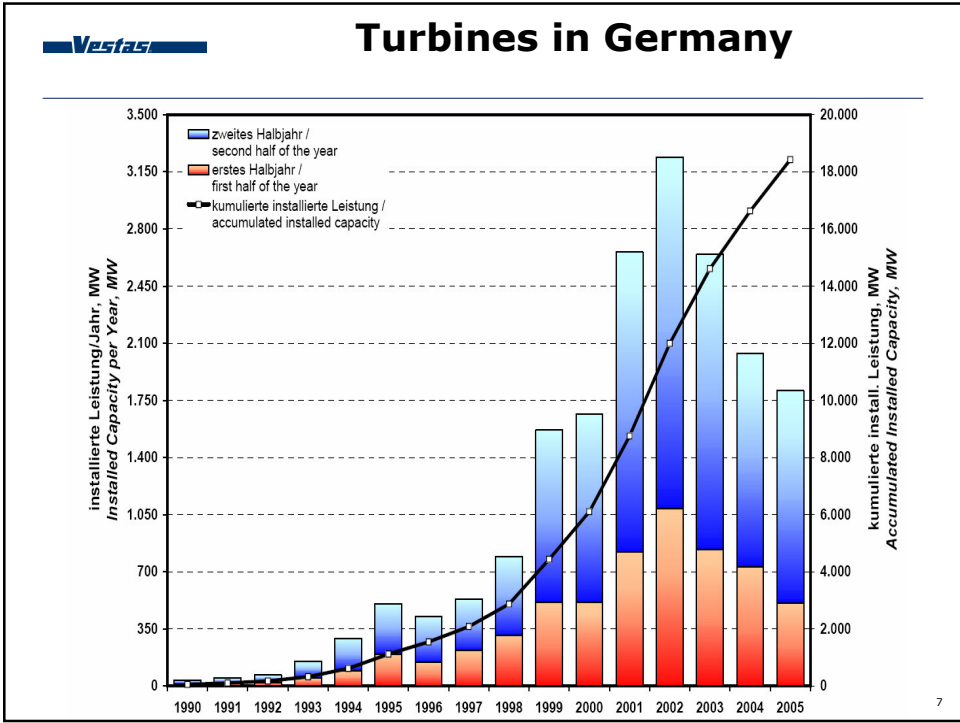
# Wind Power in Europe 2005



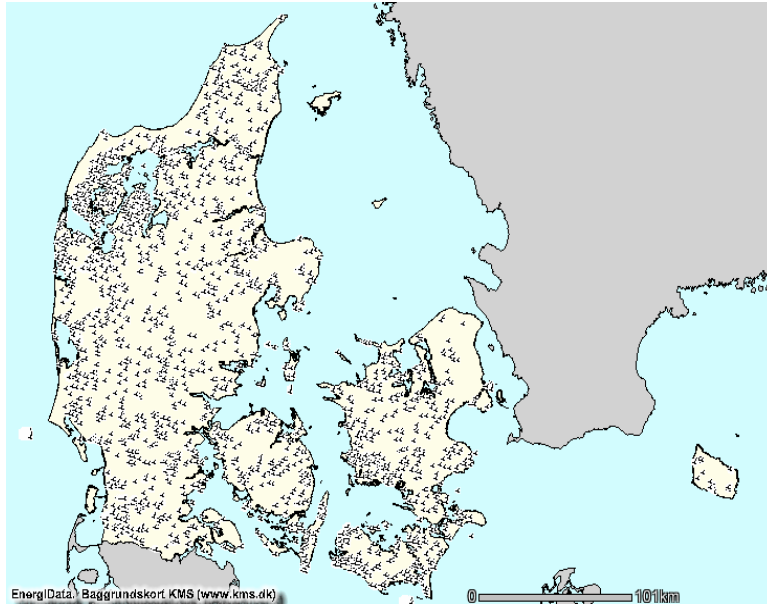
# Turbines in Denmark

Number of turbines in Denmark

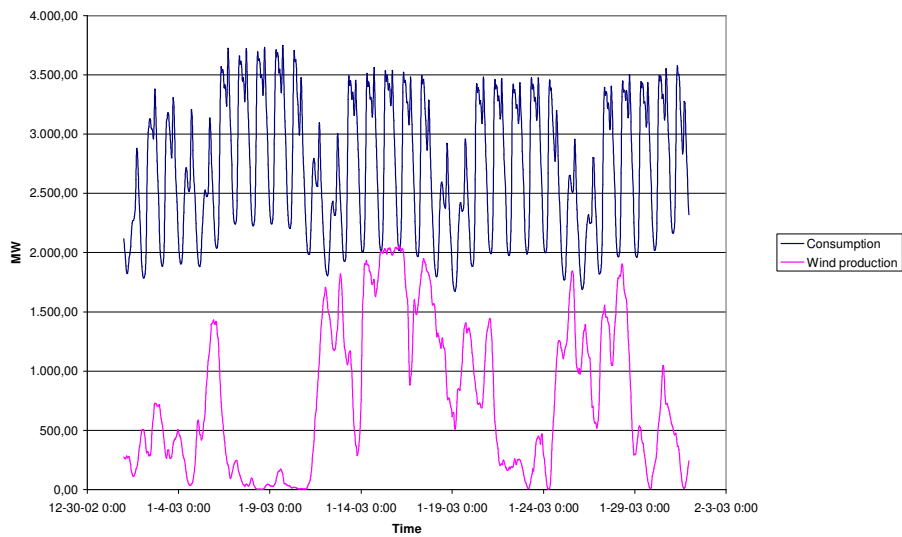




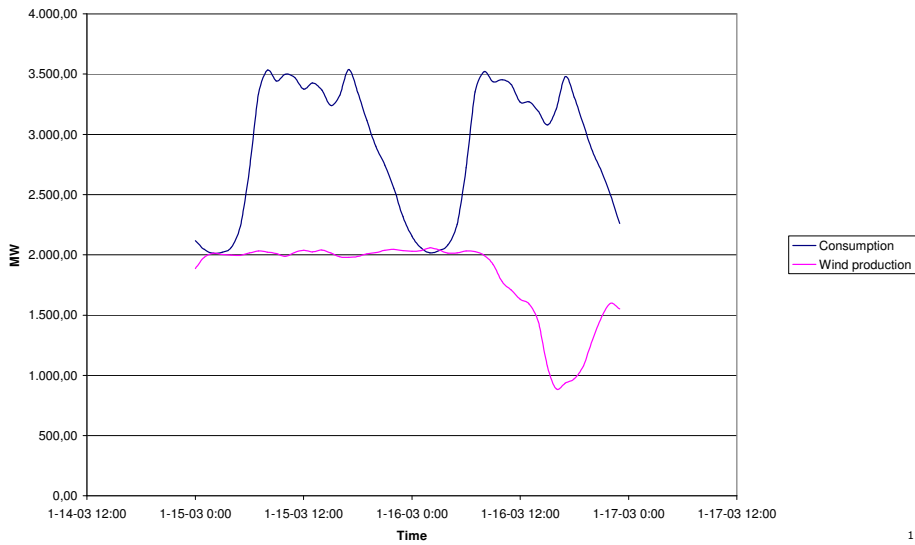
# Wind Turbines in Denmark



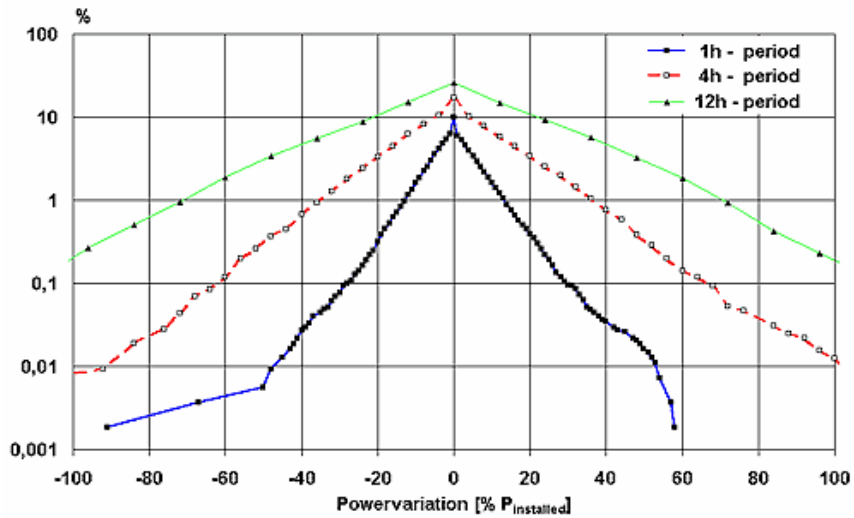
# Wind in west Denmark Penetration January 2003



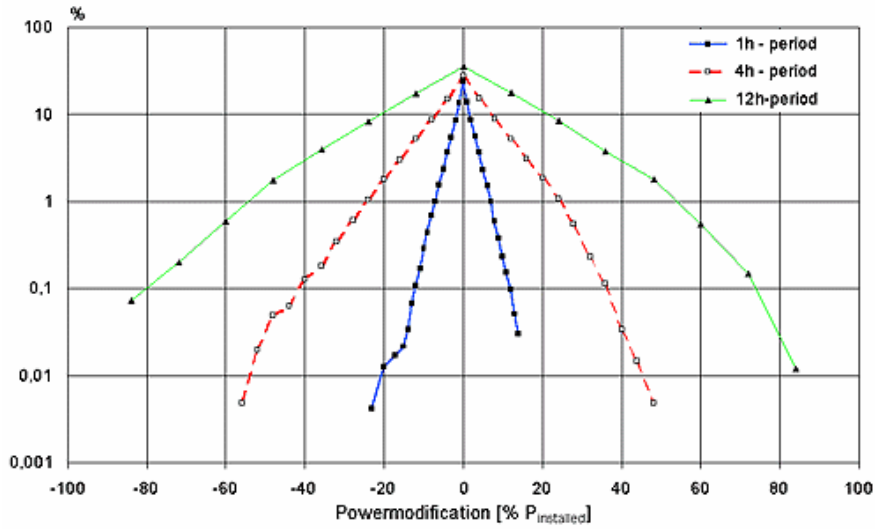
### Wind in west Denmark Penetration 15-17/1-2003



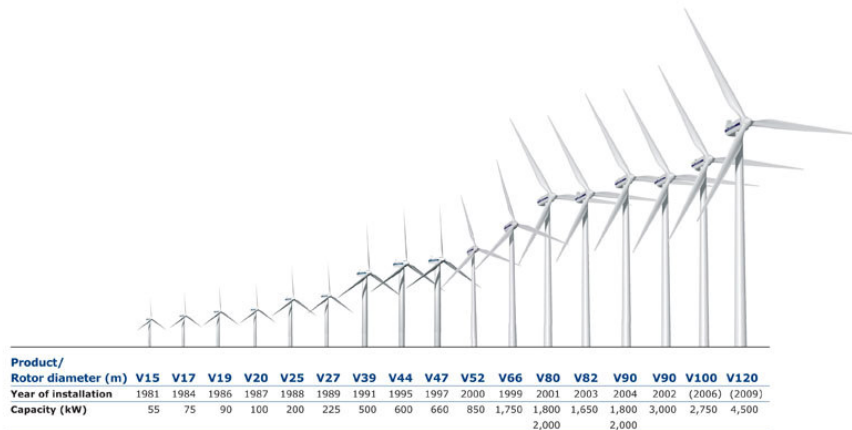
### Wind in Germany - Individual turbines



## Wind in Germany, more than 1500 turbines



## Development of wind turbines



## 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

15

## 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

16

### 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

### 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

### 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

### 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

### 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

- 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

Thank you

The logo for Vestas, featuring the word "Vestas" in a blue, italicized sans-serif font, preceded by a small blue square icon.