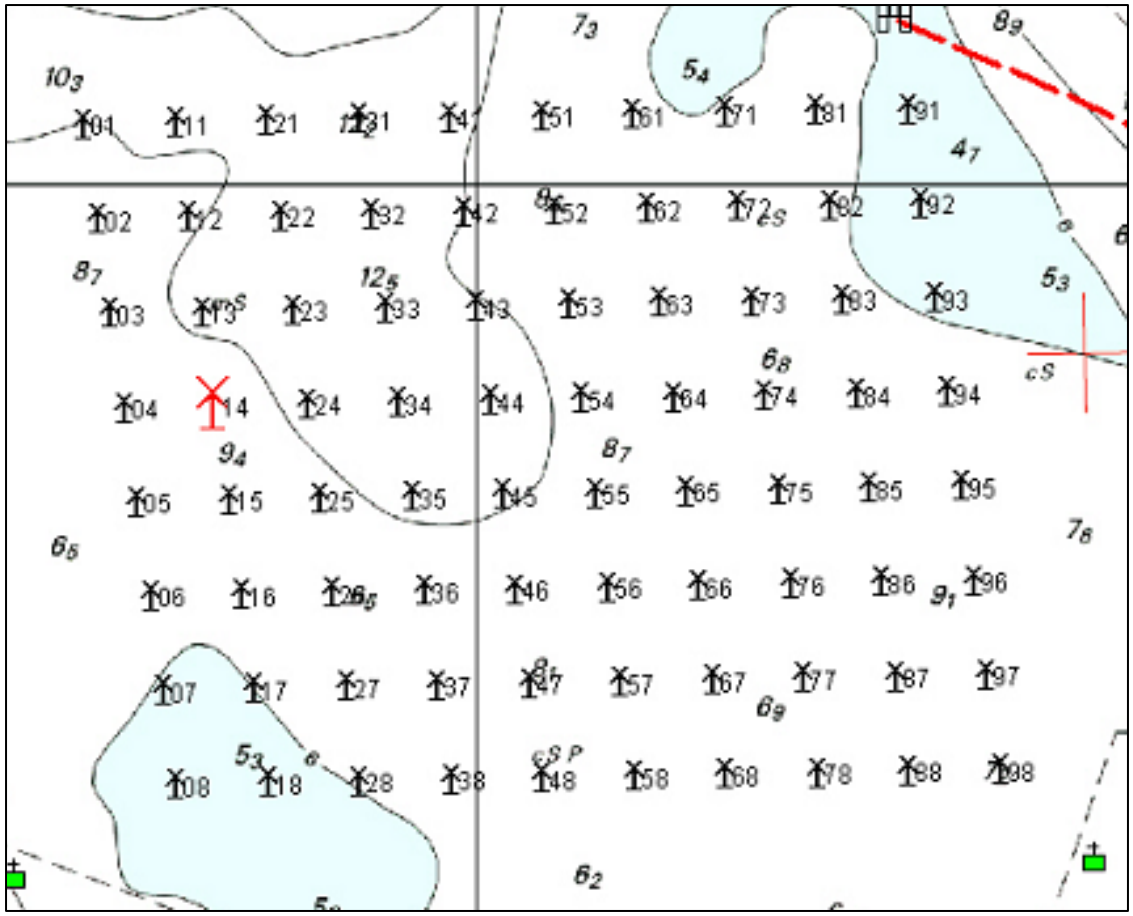
Load Response Measurements at the Horns Rev Wind Farm

Leo E. Jensen, Elsam Engineering A/S

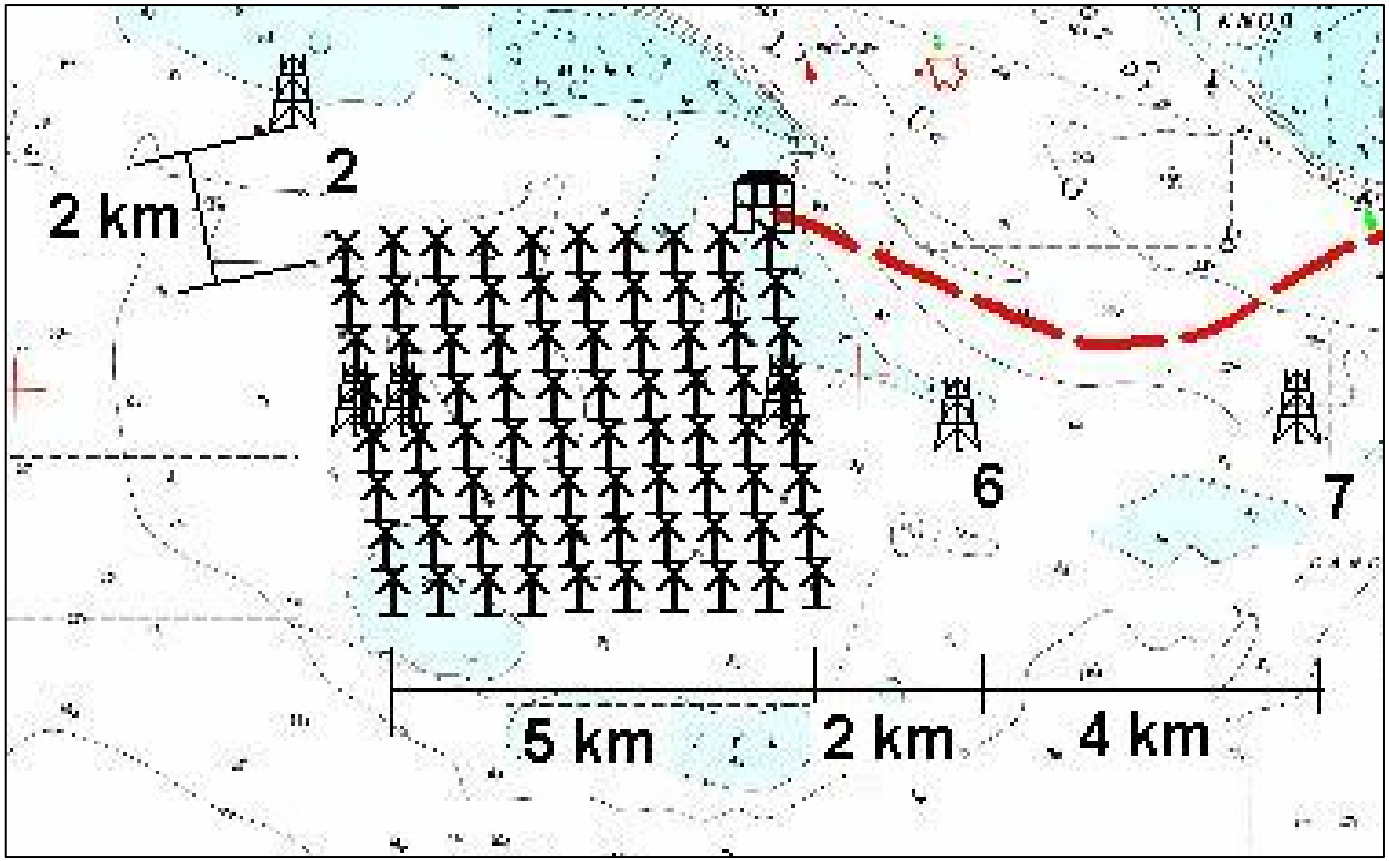
Michael Høgedal, Vestas Wind Systems A/S

Horns Rev – The engineering challenge

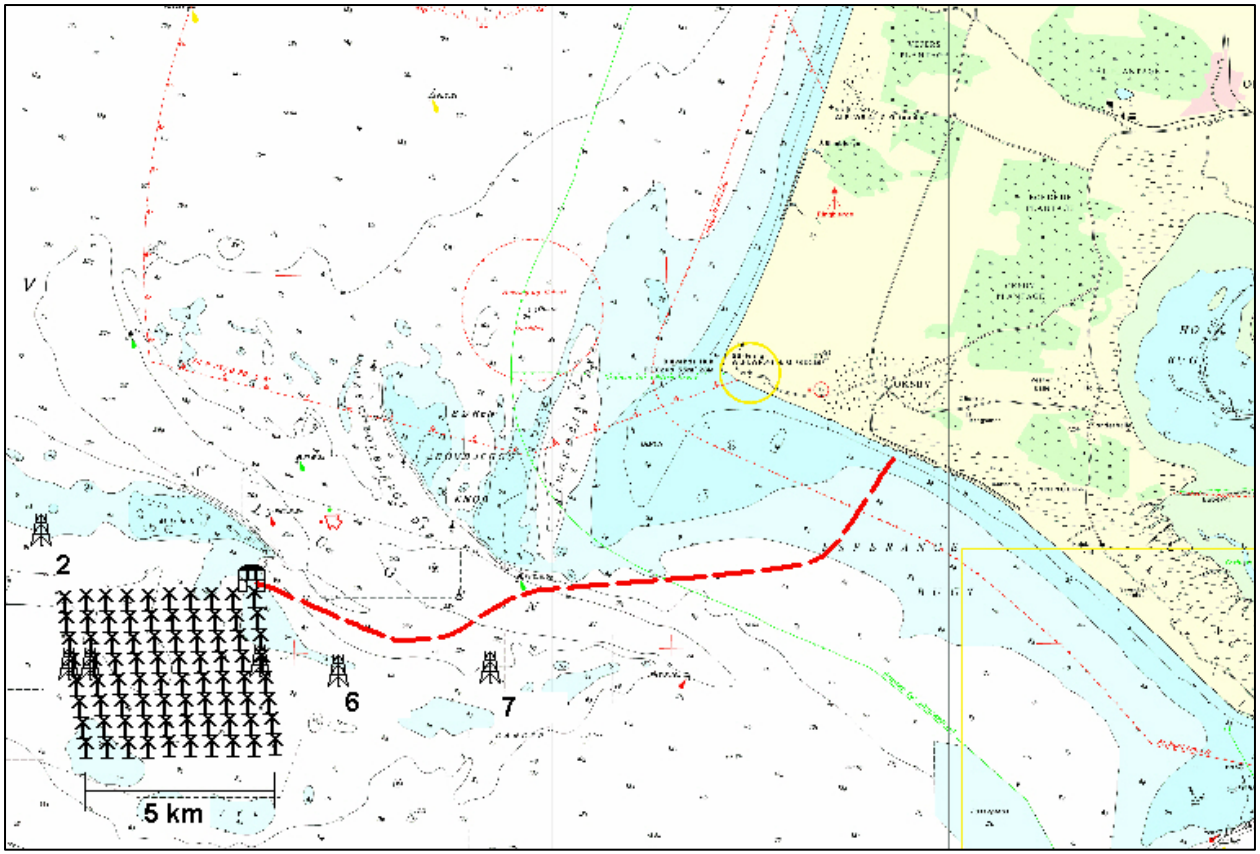
Horns Rev - Layout



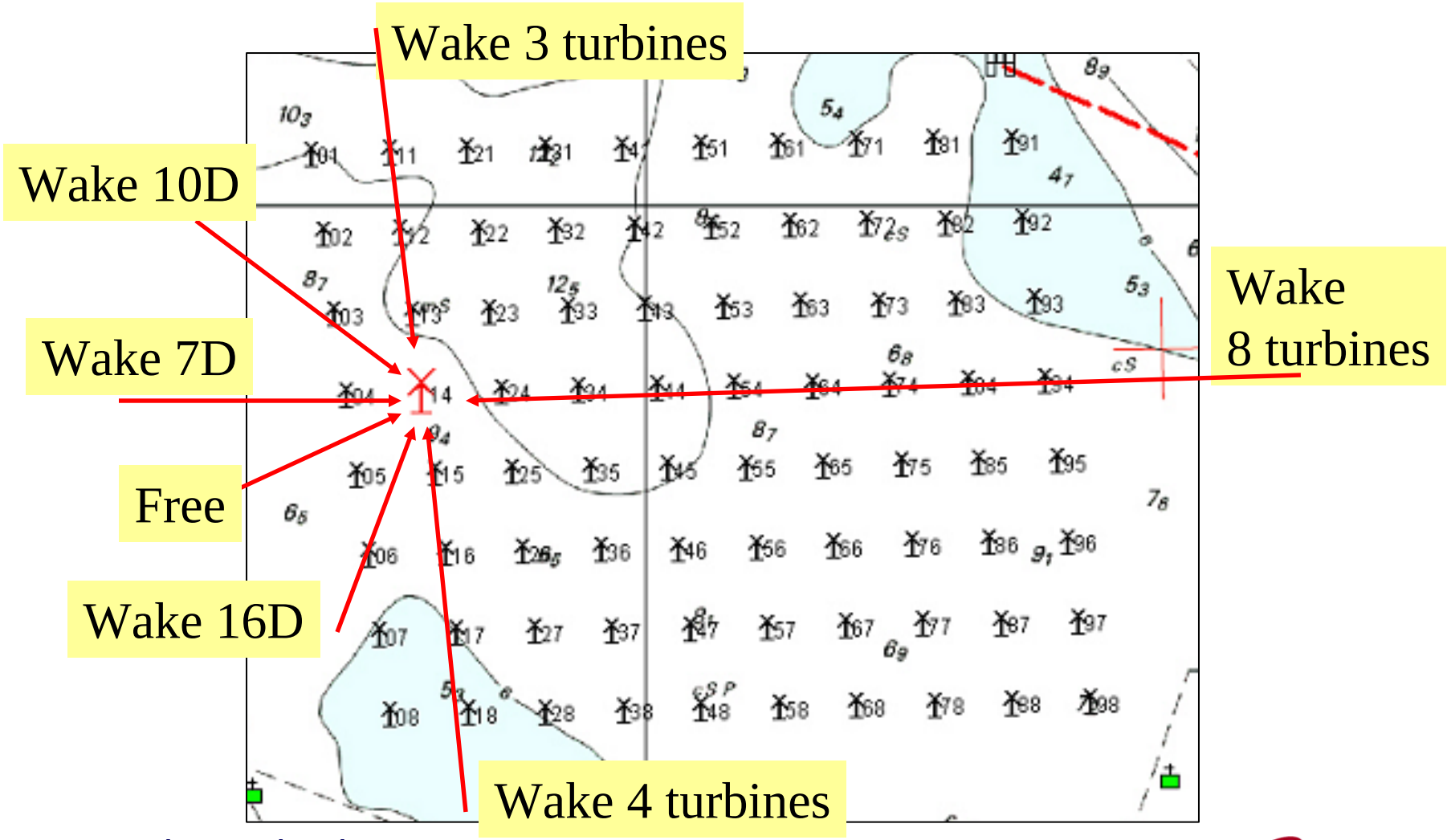
Horns Rev – Met. masts



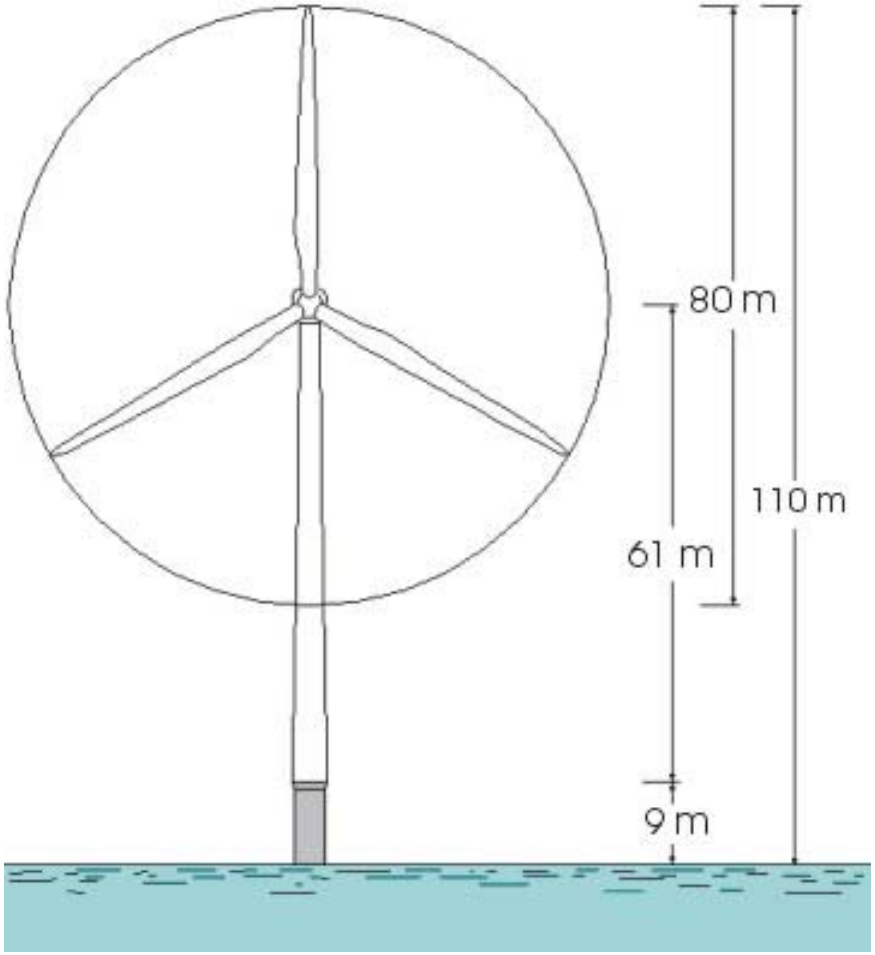
Horns Rev – Distance from land



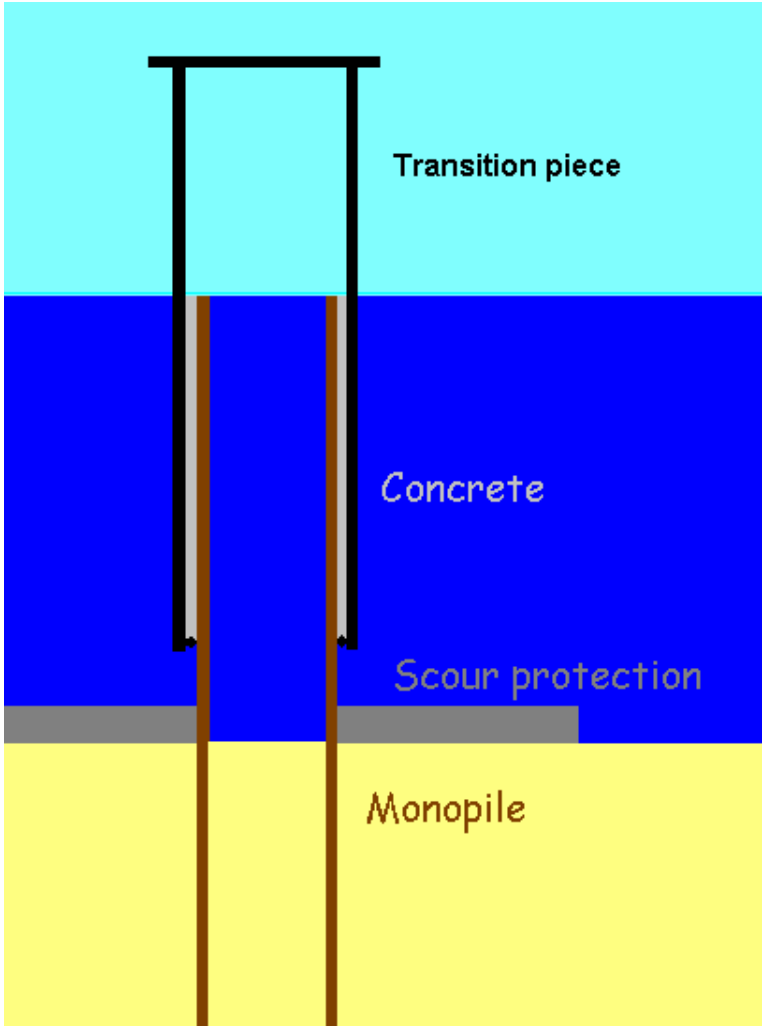
Turbine 14 – Wake situations to analyse



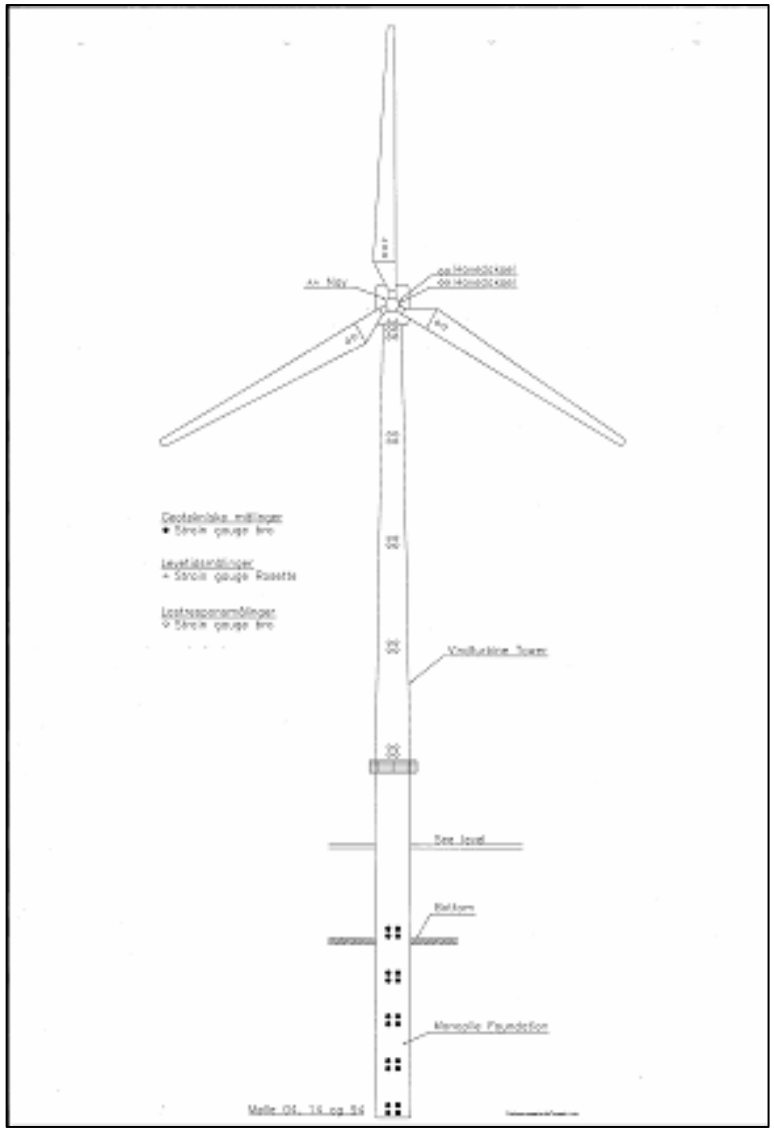
Turbine 14 - Dimensions



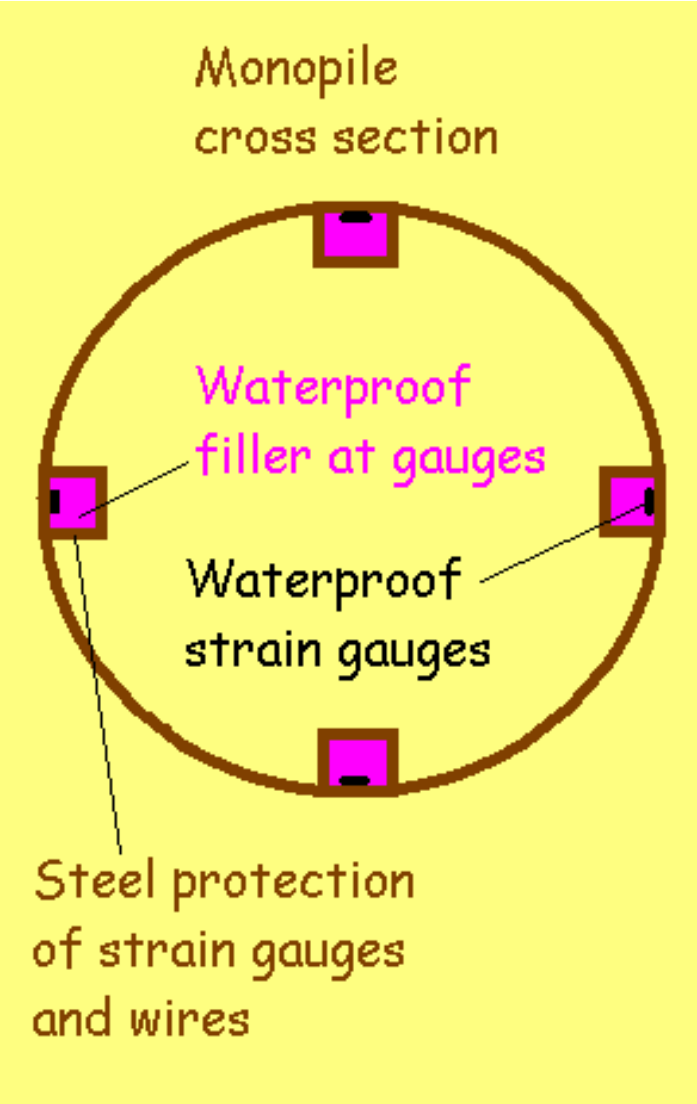
Turbine 14 – The monopile



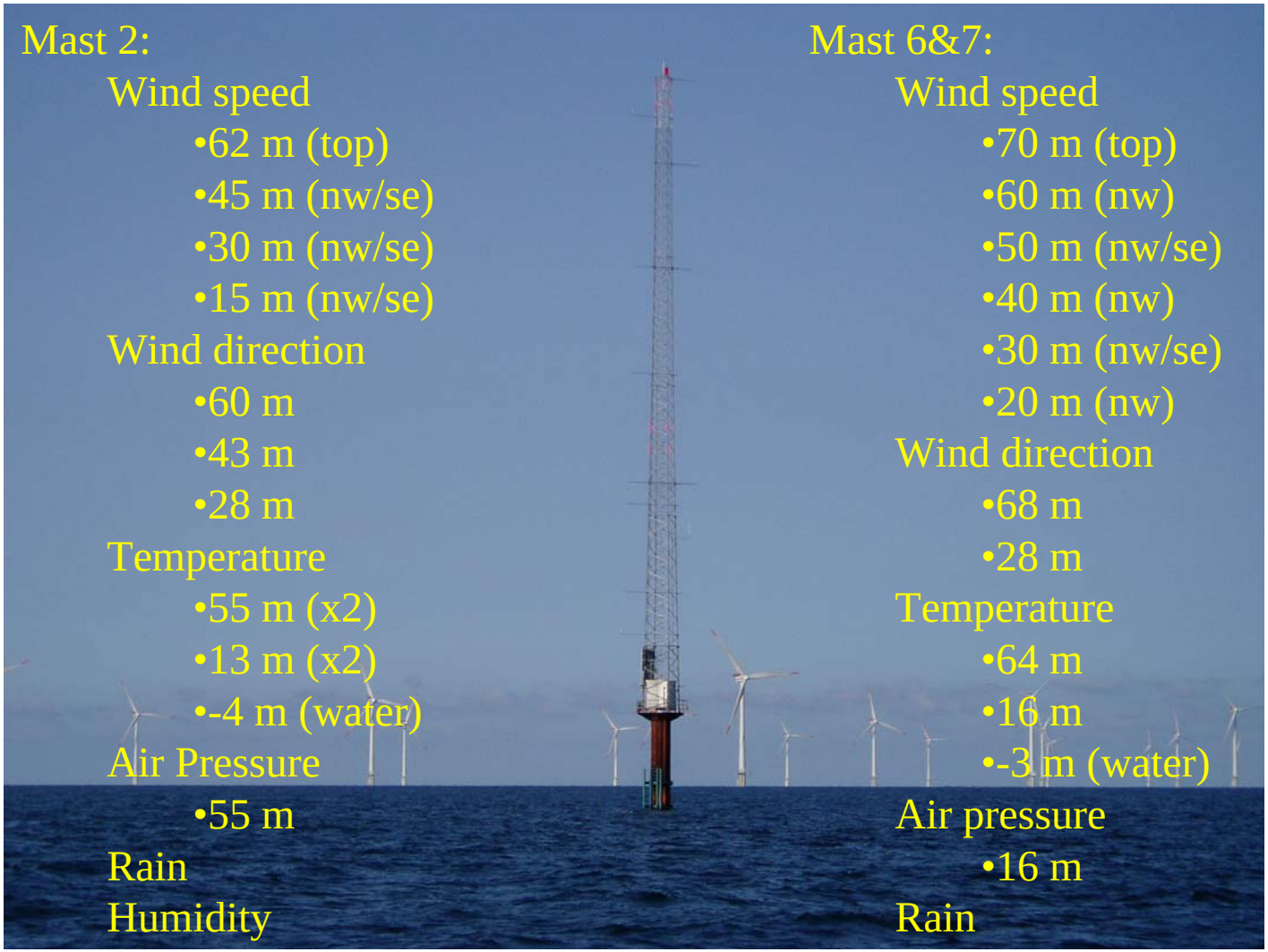
Turbine 14 – The instrumentation



Monopile – Protection of strain gauges



External data - Met. masts



Mast 2:

- Wind speed
  - 62 m (top)
  - 45 m (nw/se)
  - 30 m (nw/se)
  - 15 m (nw/se)
- Wind direction
  - 60 m
  - 43 m
  - 28 m
- Temperature
  - 55 m (x2)
  - 13 m (x2)
  - -4 m (water)
- Air Pressure
  - 55 m
- Rain
- Humidity

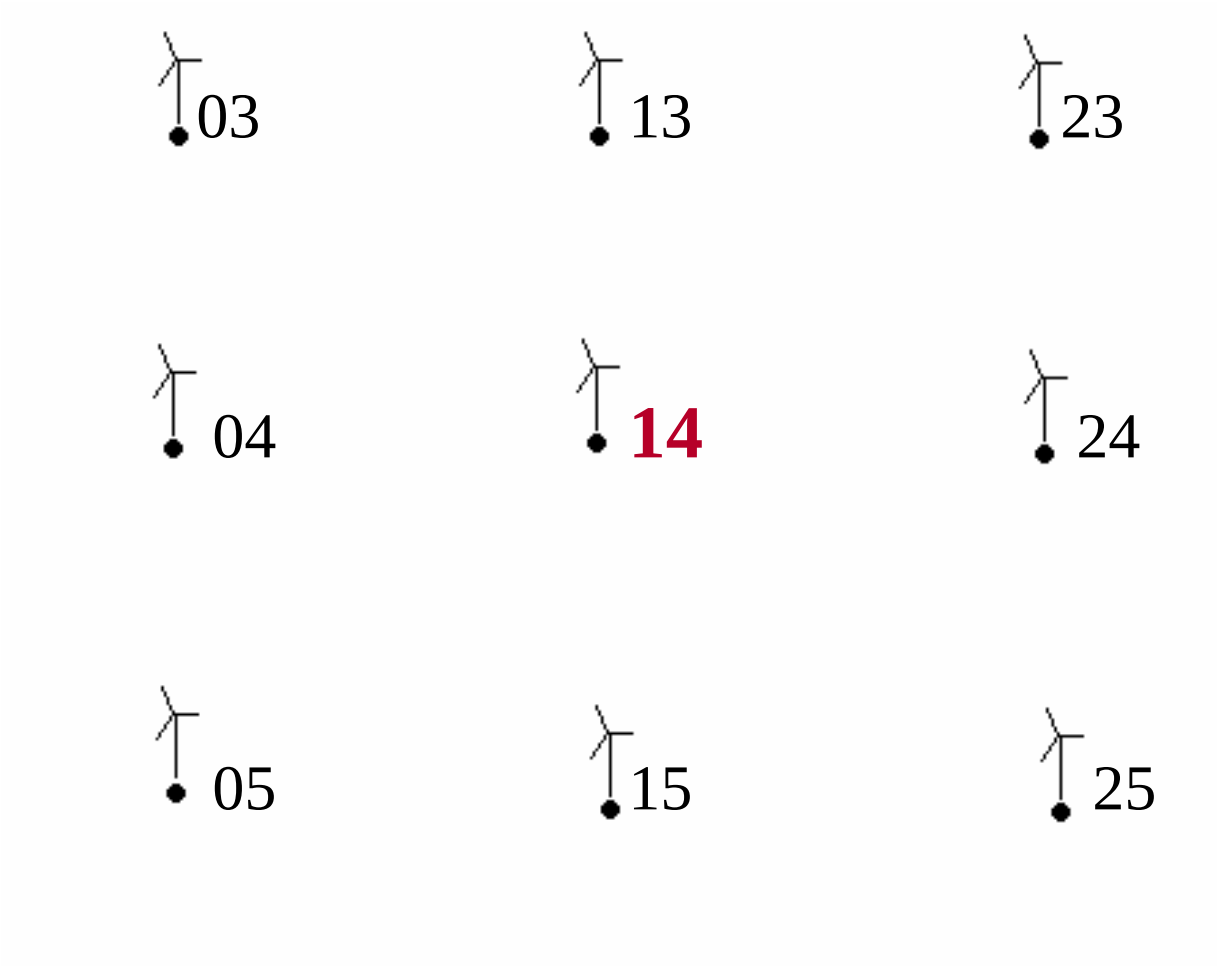
Mast 6&7:

- Wind speed
  - 70 m (top)
  - 60 m (nw)
  - 50 m (nw/se)
  - 40 m (nw)
  - 30 m (nw/se)
  - 20 m (nw)
- Wind direction
  - 68 m
  - 28 m
- Temperature
  - 64 m
  - 16 m
  - -3 m (water)
- Air pressure
  - 16 m
- Rain

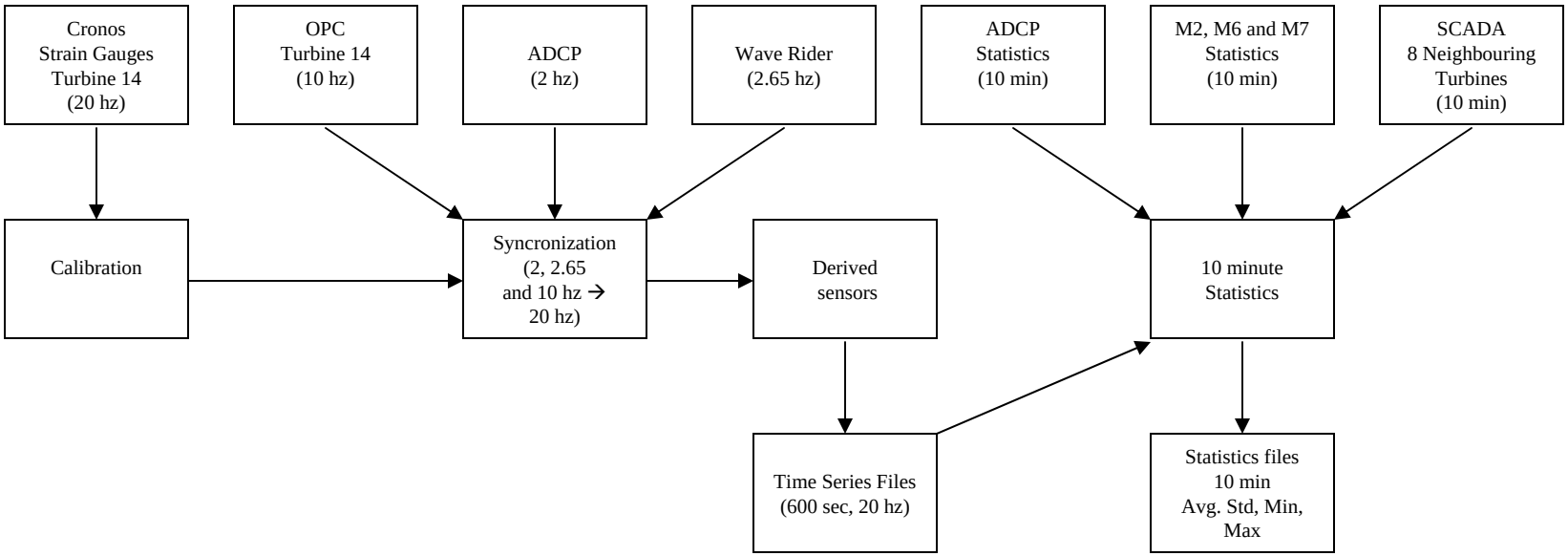
External data – wave data

External data – Wave data

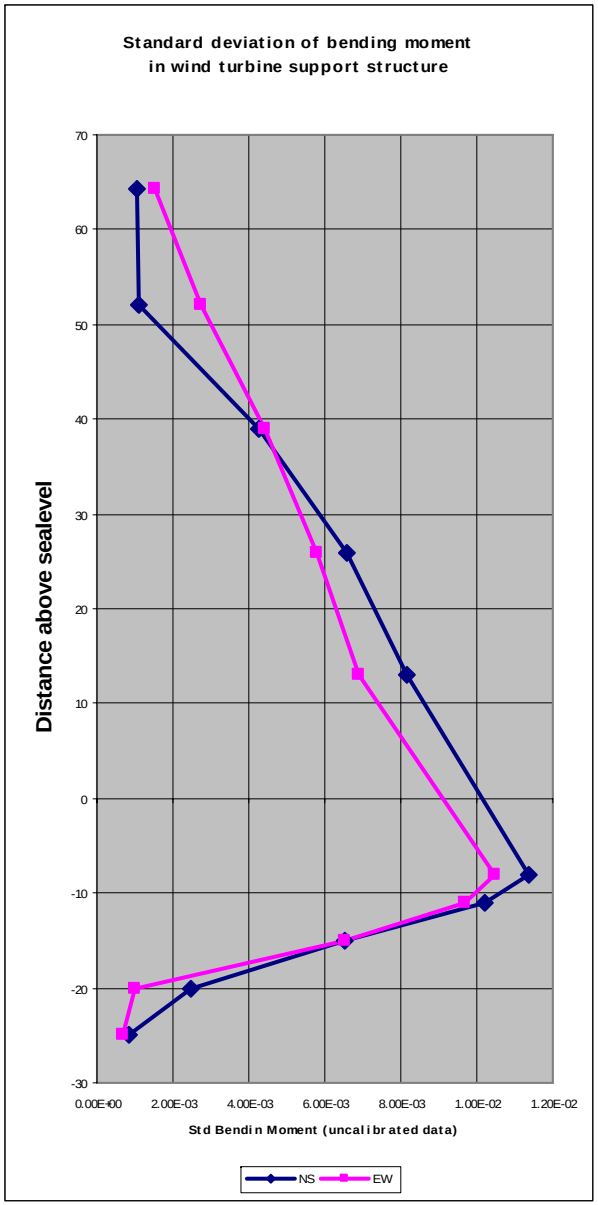
External data – Neighbouring turbines



Data flow


Cronos
Strain Gauges
Turbine 14
(20 hz)
OPC
Turbine 14
(10 hz)
ADCP
(2 hz)
Wave Rider
(2.65 hz)
ADCP
Statistics
(10 min)
M2, M6 and M7
Statistics
(10 min)
SCADA
8 Neighbouring
Turbines
(10 min)
Calibration
Syncronization
(2, 2.65
and 10 hz →
20 hz)
Derived
sensors
10 minute
Statistics
Time Series Files
(600 sec, 20 hz)
Statistics files
10 min
Avg. Std, Min,
Max

Results


Standard deviation of bending moment
in wind turbine support structure
Distance above sealevel
70
60
50
40
30
20
10
0
-10
-20
-30
0.00E+00
2.00E-03
4.00E-03
6.00E-03
8.00E-03
1.00E-02
1.20E-02
Std Bendin Moment (uncalibrated data)
NS
EW

Related R&D Projects

- **Design of offshore wind turbines**. Collecting experience from the Danish offshore pilot projects – evaluation and conclusions regarding measurements. Headed by **Risø National Laboratory** and funded by the **Public Service Obligations of Eltra and Elkraft** (now Energinet.dk).

- **Soil Structure Interaction of foundations for offshore wind turbines**. Headed by **Aalborg University** and funded by the **Danish Energy Research Programme**.

- **UPWIND**. Headed by **Risø National Laboratory** and funded by the **6th framework programme of the European Union**.

Other R&D projects?

- Extracts of data can be provided on request for specific analysis work of other non-commercial research projects, provided the work does not compromise commercial interests of Vestas or Elsam.

Contact:

- Leo E. Jensen (LEJE@ELSAM.COM), or
- Michael Høgedal (MHL@VESTAS.COM)

Concluding remarks

”1 measurement is worth more than 1000 expert assumptions”

(Founder of the Velux in Denmark)

Load response measurements

will play a key role in cutting down cost

of off-shore wind power.