Utgrunden Offshore Wind Farm:

Results of Five Years of Operation and Research

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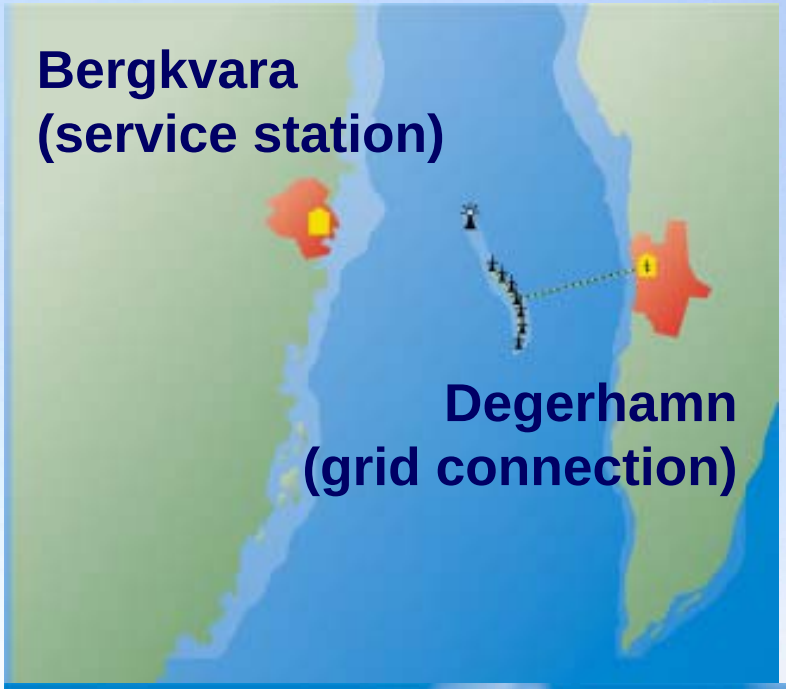

Utgrunden Project

- Planned, designed and turn-key built by Enron Wind (now GE Energy)
- 7 GE*1.5s offshore* = 10.5 MW
  1.5 MW, ø 70.5m, pitch – var. speed
- Commissioning Dec. 2000 on time & within budget
- Owned by *Energi E2*

Utgrunden research project

Technical part

- Load & eigenfrequency measurements — GE (KWK, Wintus)
- Wake effects and other loads — FOI
- Electrical performance — Chalmers
- Meteorology — Uppsala
- Operation & Maintenance — GE
- Installation — GE

Environmental part

- Bird study — GE, Vindkompaniet, J. Pettersson, Lund Univ.
- Subsea noise during installation & operation, etc.

Organisation

- Duration late 2000 – early 2005
- Technical and environmental reference groups
- Funded by Swedish Energy Authority (STEM) P11518-2
- Permission and cooperation of owner

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Design verification: GE Energy
(carried out by GE & KWK Windtest)

Soft-soft monopile structure

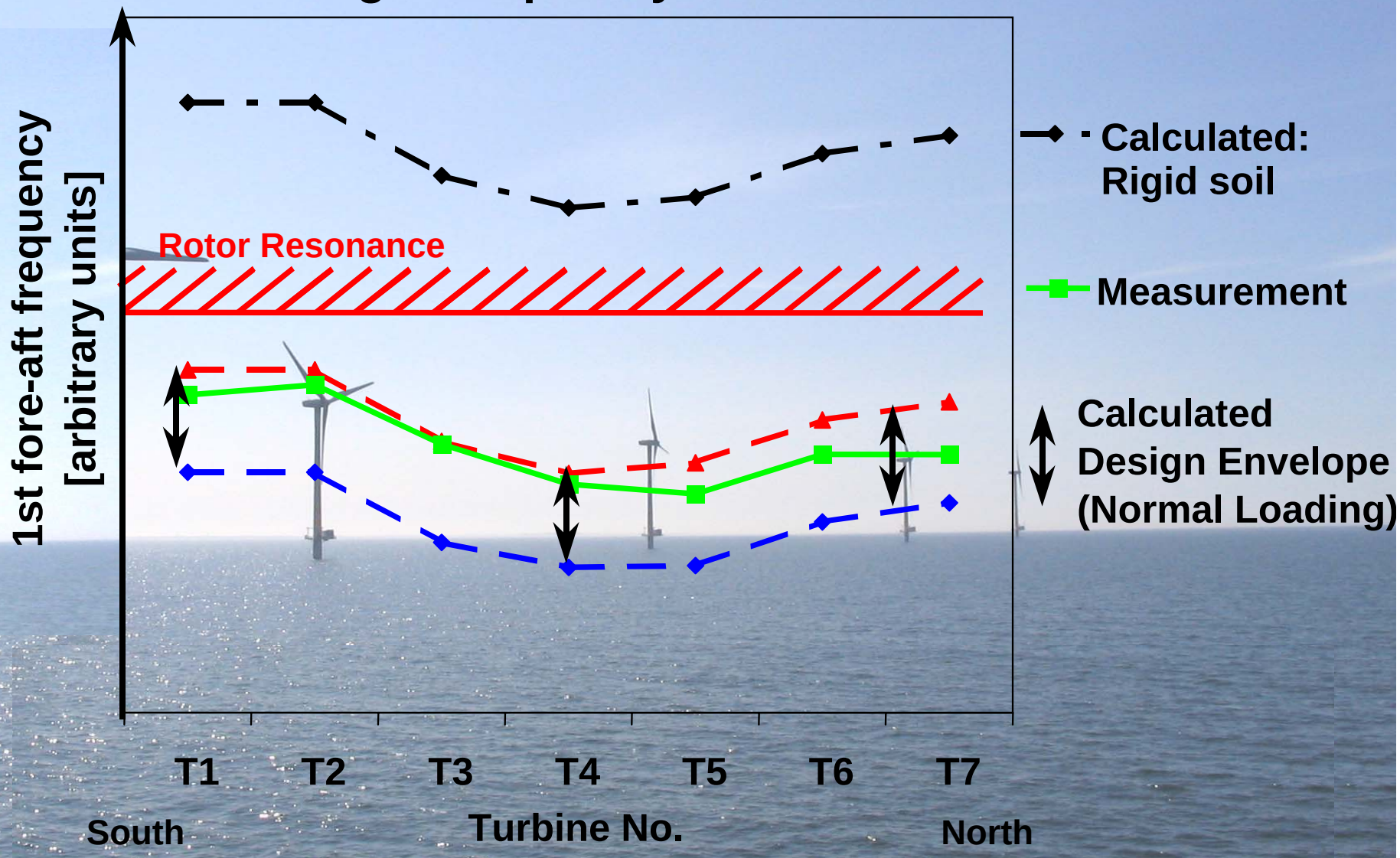
- **1st eigenfrequency below rotor speed and in the wave excitation range**
- **Weight savings w.r.t. soft-stiff design**

Objectives:

1. **Eigenfrequency measurements at all turbines**
2. **Wind and wave load measurements at one turbine with measurement system acc. to IEC 61400-12/13 with exception of met mast**

=> Verification of design assumptions

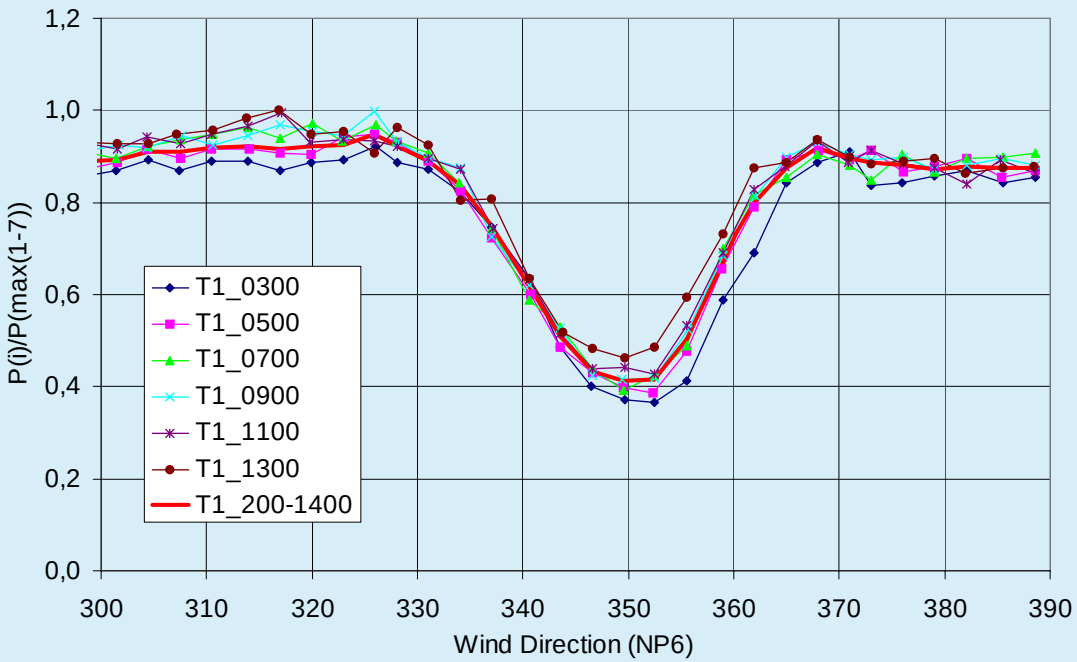
Verification of soft-soft monopile design: Eigenfrequency measurements

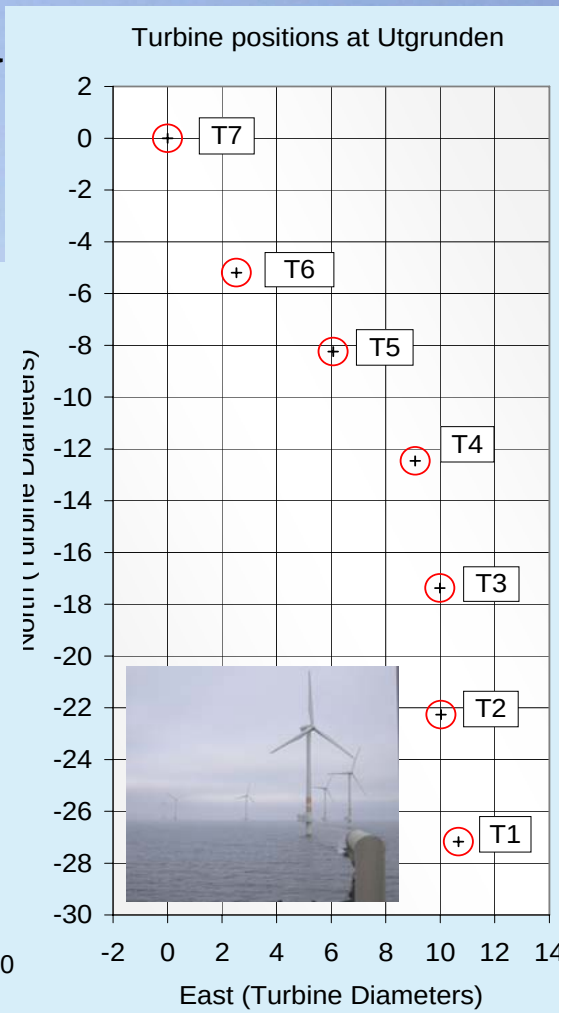


Wake effects and other loads: FOI – Department of Wind Energy

- Evaluation of load measurements and SCADA data
- Losses due to wakes and yaw misalignment
- Investigation of prospects of Active Wake Control
- Study on breaking ice loads

Relative power of T1 turbine over wind direction





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Electrical performance:

Department of Energy & Environment, Chalmers University

Grid measurements at onshore substation

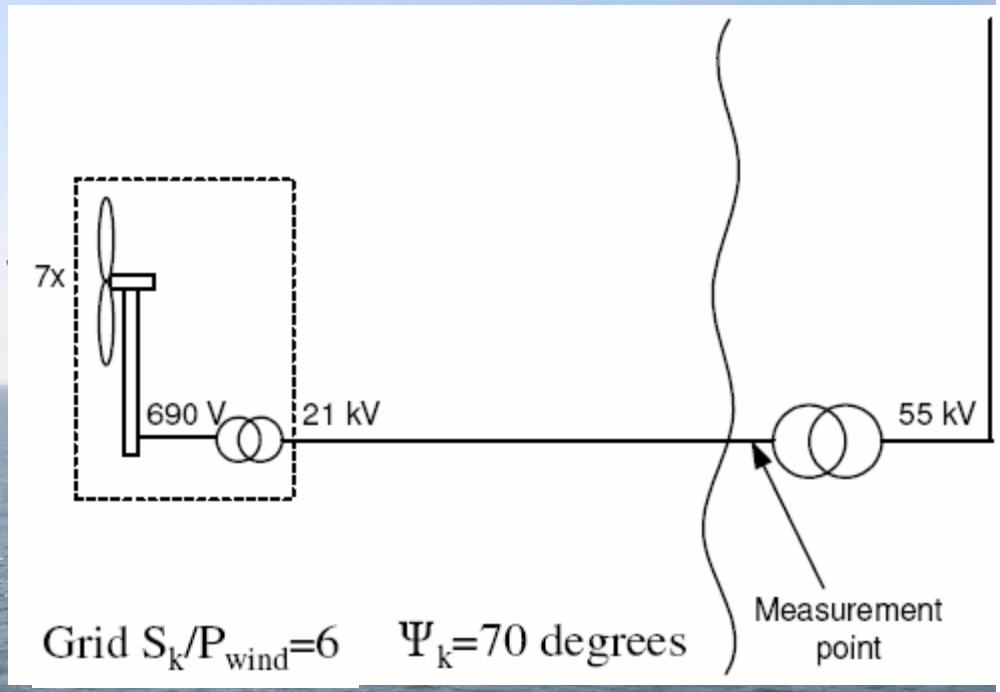
- **Reactive power exchange**
- **Response to voltage disturbances**
- **Flicker**
- **Harmonic emissions**

=> Turbines behave well

High number of voltage dips (down to 60%)
=> Turbine shut-downs

Current situation

- **Grid stability improved**
- **Ride-through not required**



Meteorology:
Metereological Institute of Upsalla University (MIUU)

- Complex wind condition in the Baltic and in Kalmar Sound, in particular
- Evaluation of wind speed measurements at Utgrunden lighthouse and turbines
- Turbine performance
- Compasion with meso-scale model of MIUU

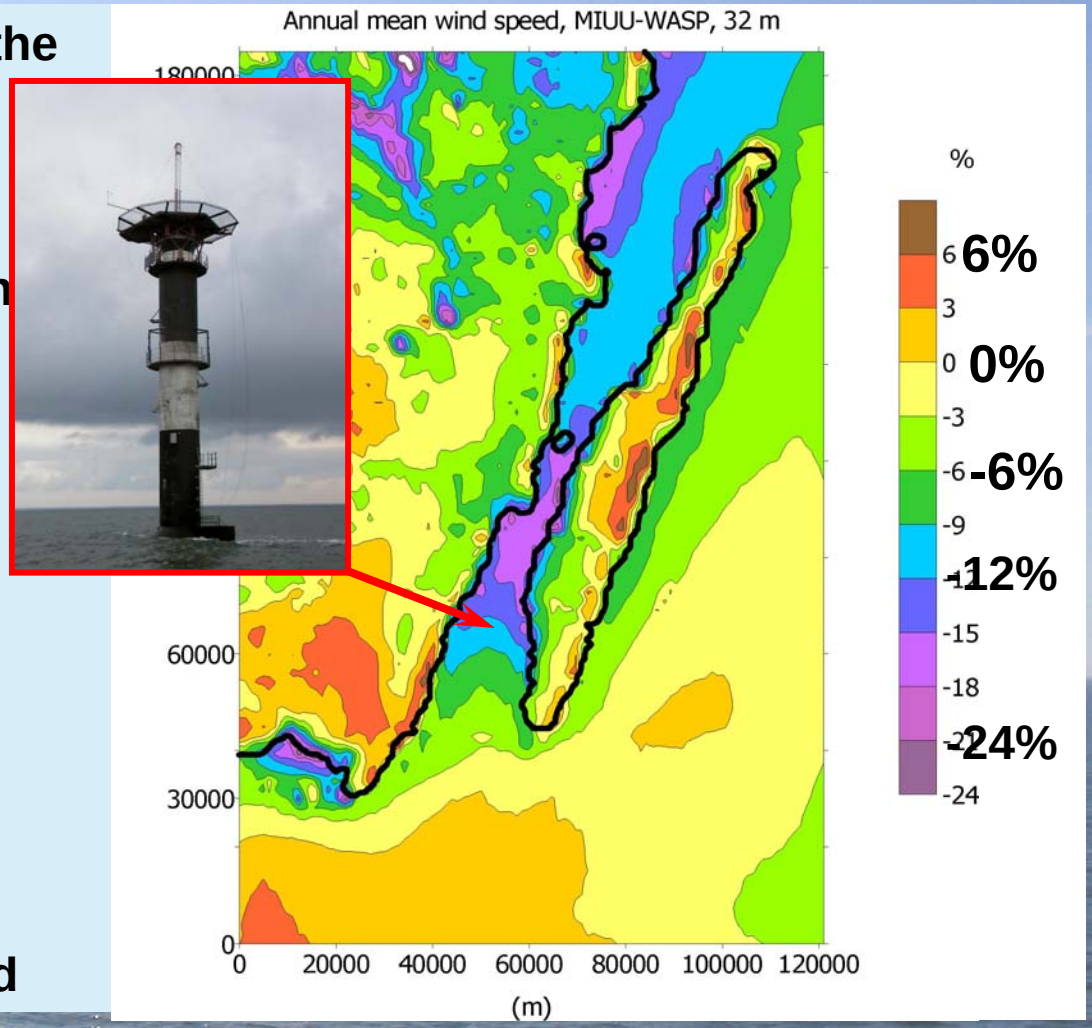


Figure:

%-Difference in annual average wind speed: MIUU – WASP
=> Large difference in complex locations, like Kalmar Sound

Operation & Maintenance (i): GE Energy Operation & Reliability

Production

- 2001-2004: Average production 30 GWh/a
- More than 50% higher yield than at best German onshore sites

Design modifications

- for offshore site, reliability & maintenance, e.g. container, crane systems, etc.

Faults

- Mean time between failure (MTBF) similar to onshore
- Mean time to repair up to 3 times higher
- Grid faults cause significant downtime, 20% of visits, brake problems

Most problems related to:

- Gear box, pitch system, frequency converter and brake

Operation & Maintenance (ii): Access

- Only one access system
  => Problems in crosswinds and waves
- Simulation study showed accessibility increase by 15-20% due to purpose-built catamaran and 2nd ladder
- Icebreaker required in winter period,
  high stand-by cost might be compensated by extra energy gain

First service vessel

Icing of access ladder

Icebreaker

Installation (i): GE Energy

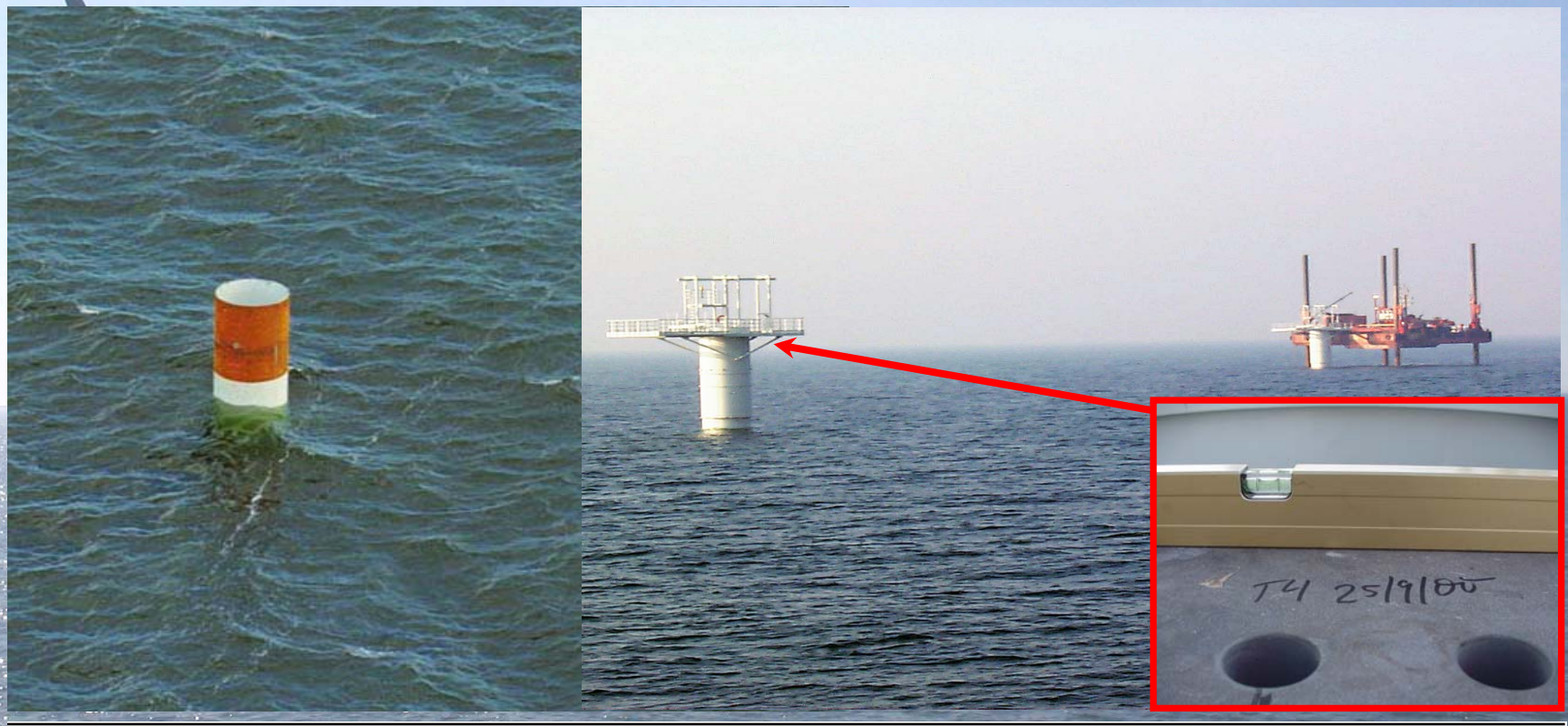
Heavy operations almost without weather delay

Importance of:

- **Logistics: manufacturing, transport, storage, lifting**
- **Grid connection: contractual and technical spec**
- **Pre-commissioning**
- **Access during commissioning period**

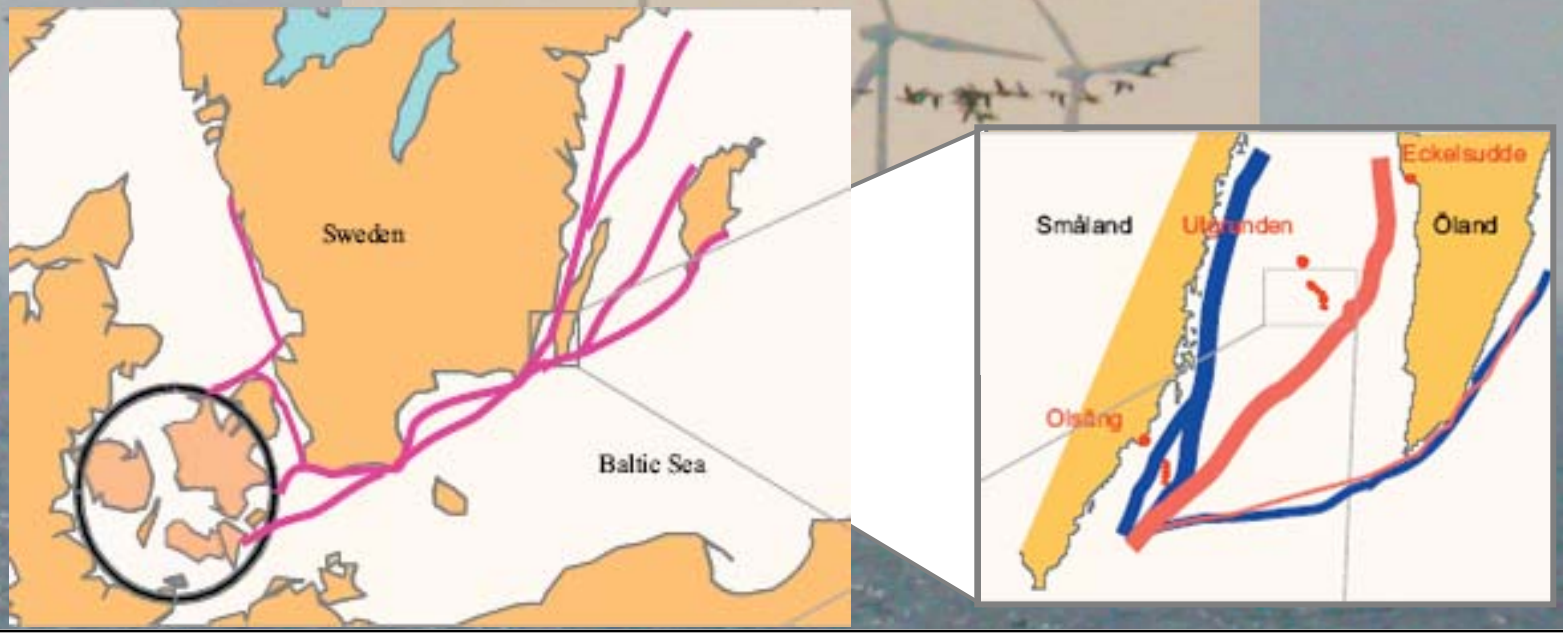
Installation (ii): Grouted Joint

- First application to offshore wind energy
  => now industry standard
- Good performance during installation and after 5 years



Environmental issues: Bird study (i)

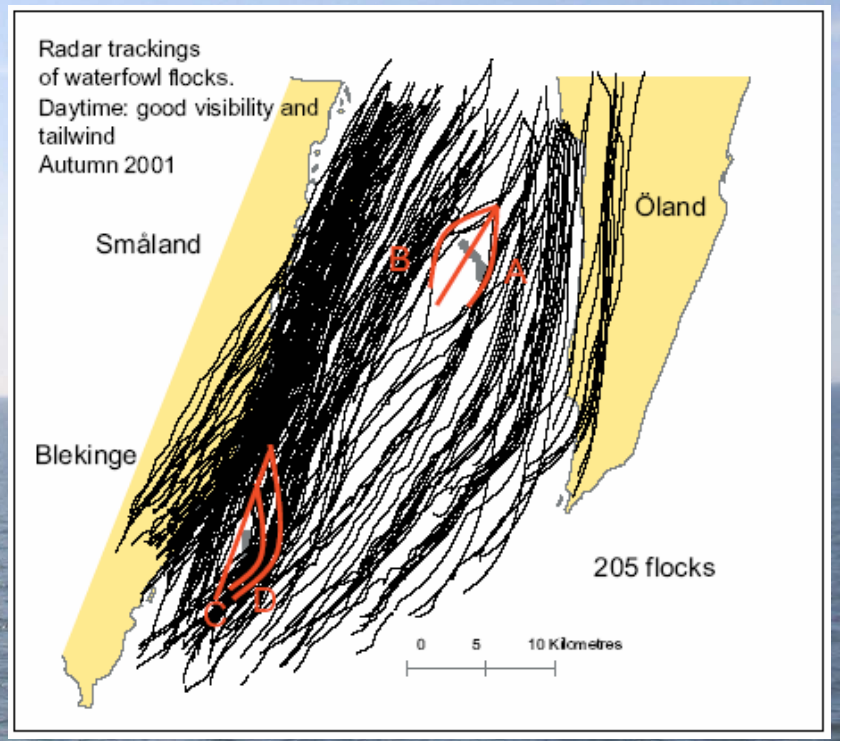
- About 1.5 million migrating birds per annum
- 4 spring & 4 autumn seasons from 1999-2003
- Impact of Utgrunden and Yttre Stengrund wind farm
  1. Migration corridors
  2. Collision risk
  3. Food-searching behaviour
- Cooperation with Vindkompaniet AB



Environmental issues: Bird study (ii)

Main observations

- Approx. 30% of migrating bird in Kalmar Sound affected
- Birds detect even at poor visibility and during night
- *Evasion manoeuvre* starting 1-2 km in front of turbines
- Extrapolated *collision* risk: approx. 1 bird/turbine/year
- Few *disturbance* of resting waterfowl, service boats more disturbing than turbines itself



Conclusions

First offshore wind farm with MW-class turbines evaluated by comprehensive international research project

1. **Soft-soft monopile viable & beneficial**
2. **Complex meteorological conditions**
3. **Lesons learnt on reliability and accessibility**
4. **Installation experience e.g. grouted joint, logistics**
5. **Bird study**
6. **Very positive perception by locals and media**

- **Support of Swedish Energy Authority (STEM)**
- **Executive Summary available at STEM**

=> Experience used for next projects, e.g. Arklow Bank

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