ECN
Your energy. Our passion.

Health monitoring

How to move to predictive maintenance?

Rotterdam
23 January 2013

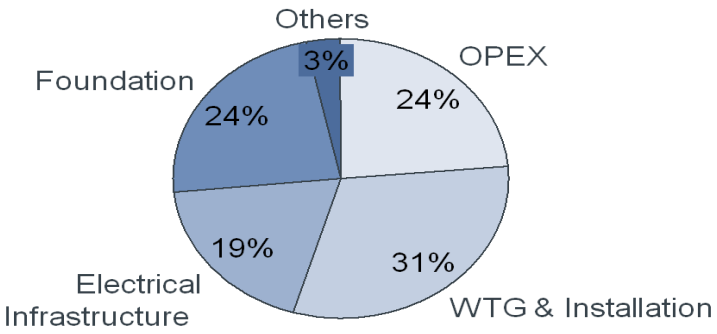
www.ecn.nl

Contents

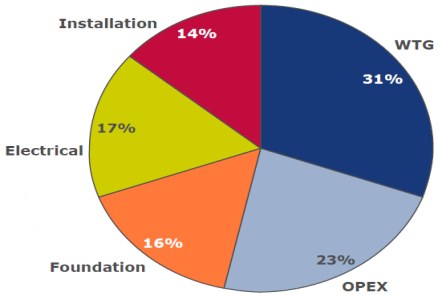
- Introduction
  - Why predictive maintenance?
  - What do we need?
- Load monitoring (ECN's approach)
  - FOBM load measurement system
  - FleetLeader for wind farm load monitoring
- Summary

Why predictive maintenance?

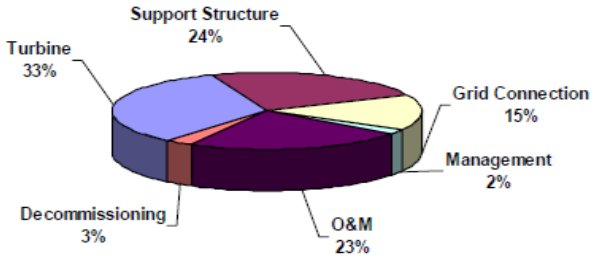
- Current practice:
  - Preventive maintenance campaign 1 or 2 times per year
  - Corrective maintenance after unexpected failures → long downtimes and high repair costs
- Result:



Vestas, 2011



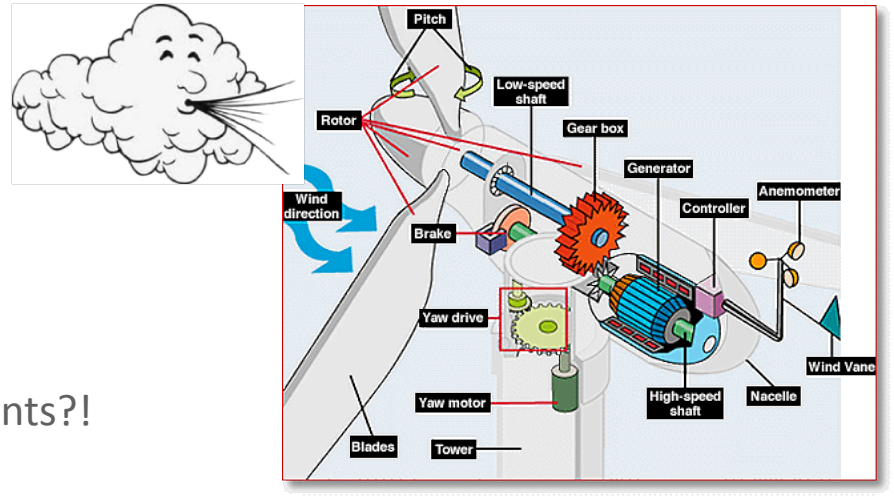
EWEA, 2011



NREL

Why predictive maintenance?

- Components to be maintained
  - Lot of rotating equipment
  - Loaded stochastically
    - Variable wind speed / turbulence
    - Effect of wakes / starts & stops
  - Large differences in lifetime of components?!



- Working offshore
  - Large ships for hoisting → expensive
  - Harsh weather conditions:
    - Long downtimes → revenue losses
    - Cost ships when waiting

What do we need?

- Condition Monitoring (CM); *online, offline, inspections, vibration, etc.*
  - Detection when degradation is present

- Load Monitoring / Usage monitoring (*possibly together with CM*)
  - Degradation of components can be predicted before something is “wrong”
  - Root cause analyses (added value for CM systems)
  - Requirement: degradation related to loading!!

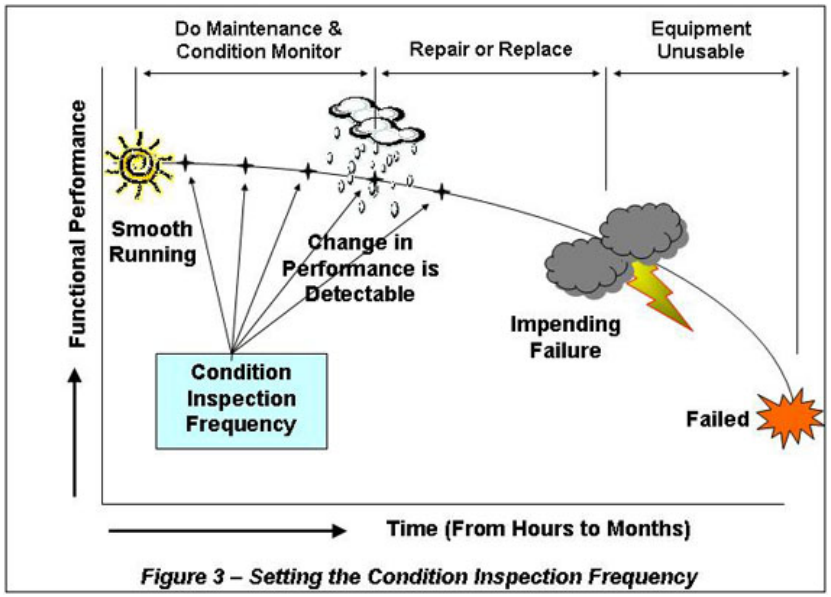


Figure 3 – Setting the Condition Inspection Frequency

Load monitoring: ECN's approach

LoadWizard

- Service that ECN provides to operators and OEM's of offshore wind farms.
- Periodical reporting of:
  - Loads on all turbines in an offshore wind farm
  - Advice about optimization of O&M
- Information assists in shifting from corrective and preventive maintenance to predictive maintenance.
- Predictive maintenance lowers O&M costs by reducing unplanned standstill and expensive consequence damages.
- Potential savings are estimated 0.1-5 M€/year for typical 500 MW farm.
- Provides high level of knowledge for O&M and design optimisation.

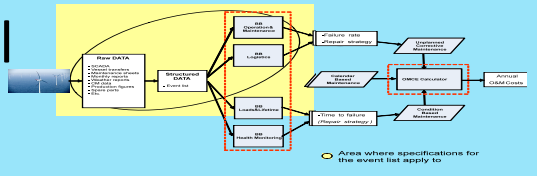
LoadWizard

O&M Advice

Loads reporting

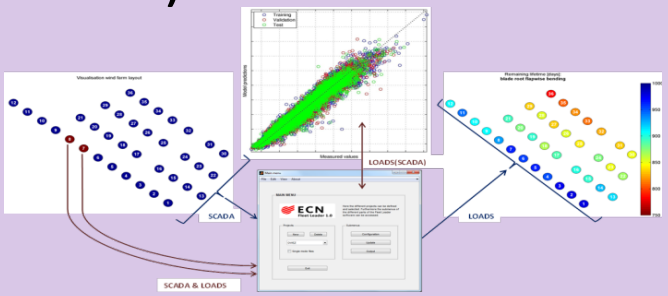
OPEX Cost Modeling Tools

- O&M Tool
- OMCE



Other CMS system

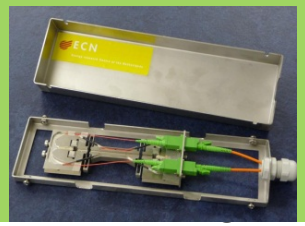
2) Fleet Leader



1) Measurement Infrastructure

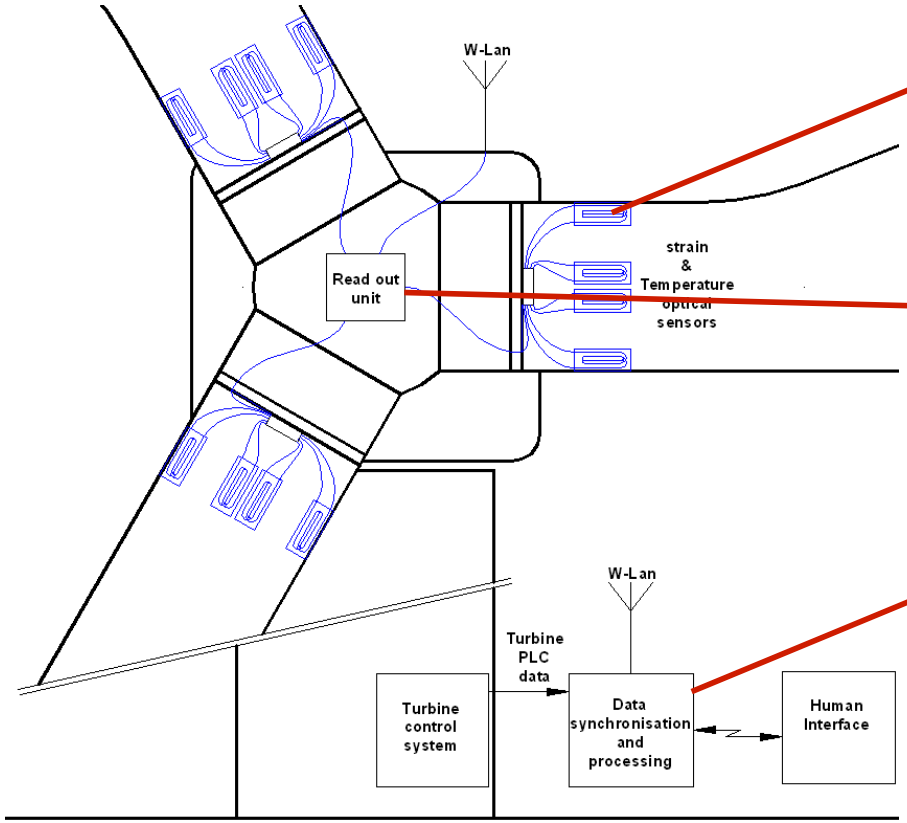
- Hardware
- Software
- Procedures

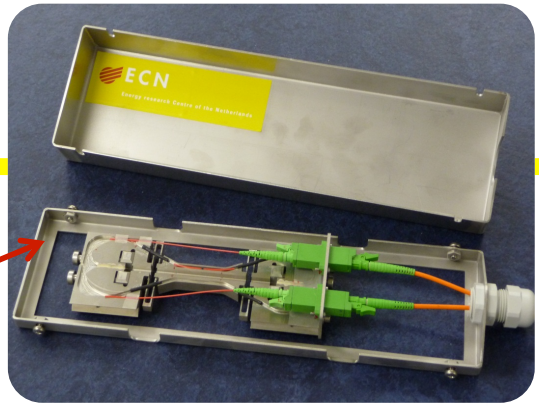
FOBM

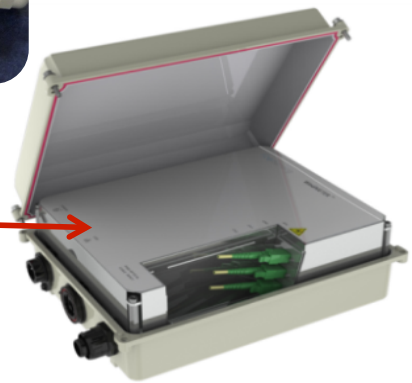


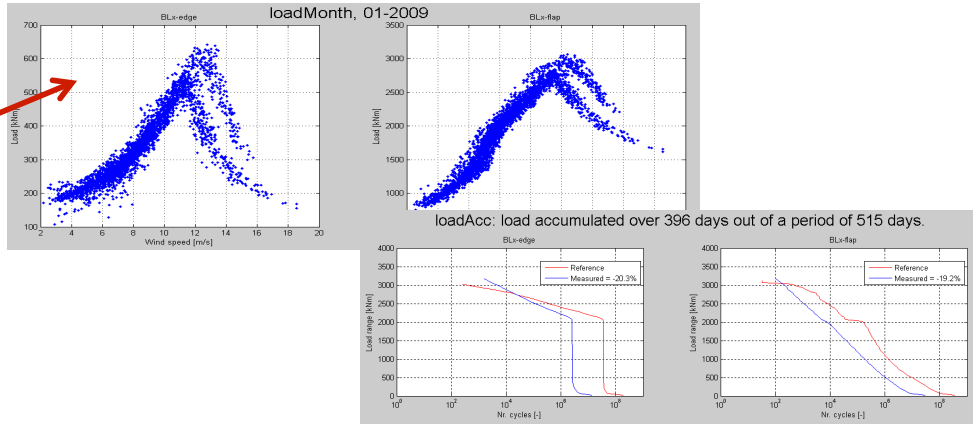
Measurement infrastructure: FOBM

FOBM: Layout


W-Lan
Read out unit
strain & Temperature optical sensors
W-Lan
Turbine PLC data
Turbine control system
Data synchronisation and processing
Human Interface


ECN

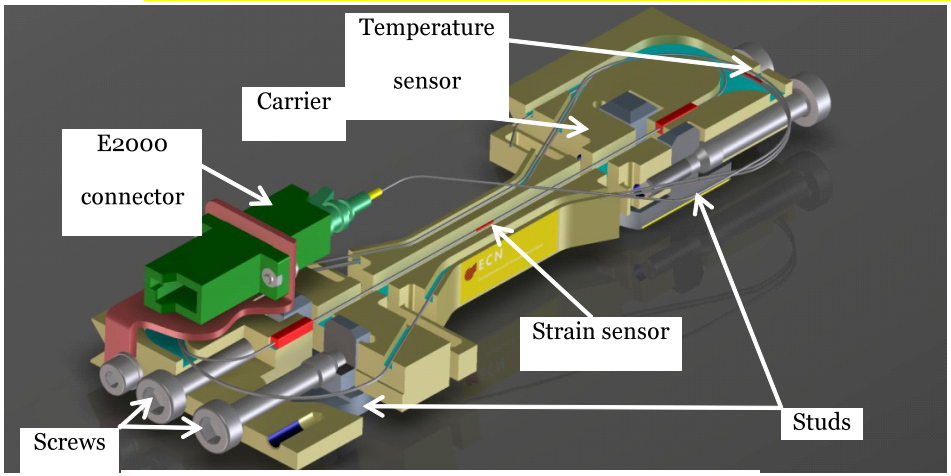



loadMonth, 01-2009
BLx-edge
BLx-flap
Load [kNm]
Wind speed [m/s]
loadAcc: load accumulated over 396 days out of a period of 515 days.
Reference
Measured = -20.3%
Measured = -19.2%
Load range [kNm]
Nr. cycles [-]

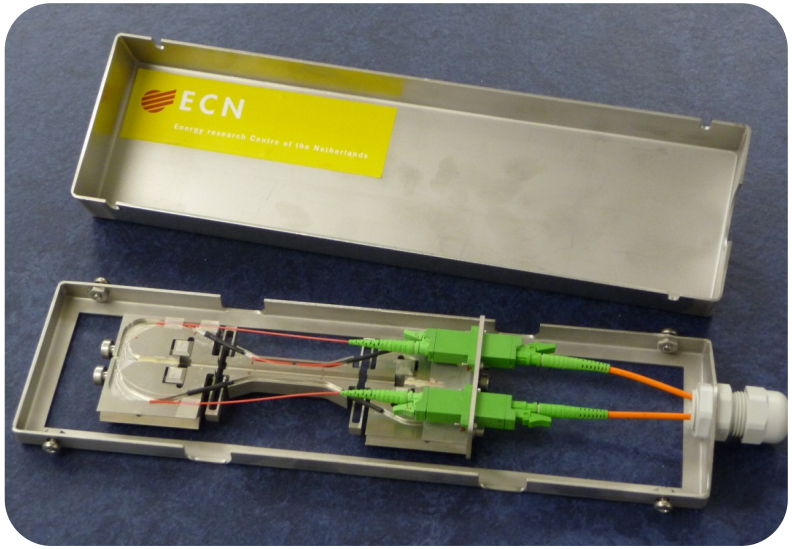
FOBM: Specifications

- The sensor assembly is easy to install and replace by regular wind turbine maintenance technicians (Plug-and-Play).
- The entire system can be installed by the technicians in less than two days.
- On-site (chain) calibration is superfluous after replacement of the sensor.
- The sensor has the same lifetime as the rotor blade.
- Technical data:
  - Strain resolution: 1 με
  - Strain accuracy / stability: better than 5 με
  - Maximum strain level: -1000 ….+1000 με
  - Long term drift: less than 5 με in one year
  - Temperature range: -20…+40 ^{o}C
  - Long life time : > 10^{7} cycles @ ±1000 με

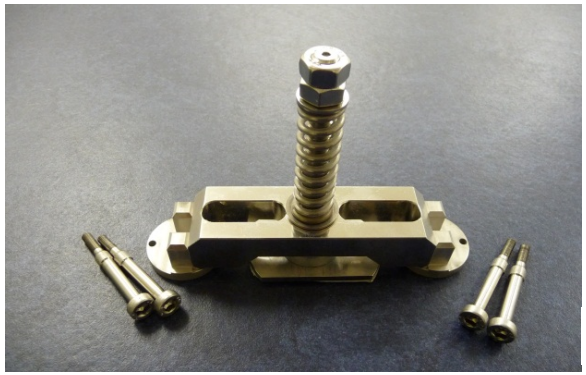
FOBM: Sensor development



Sensor design

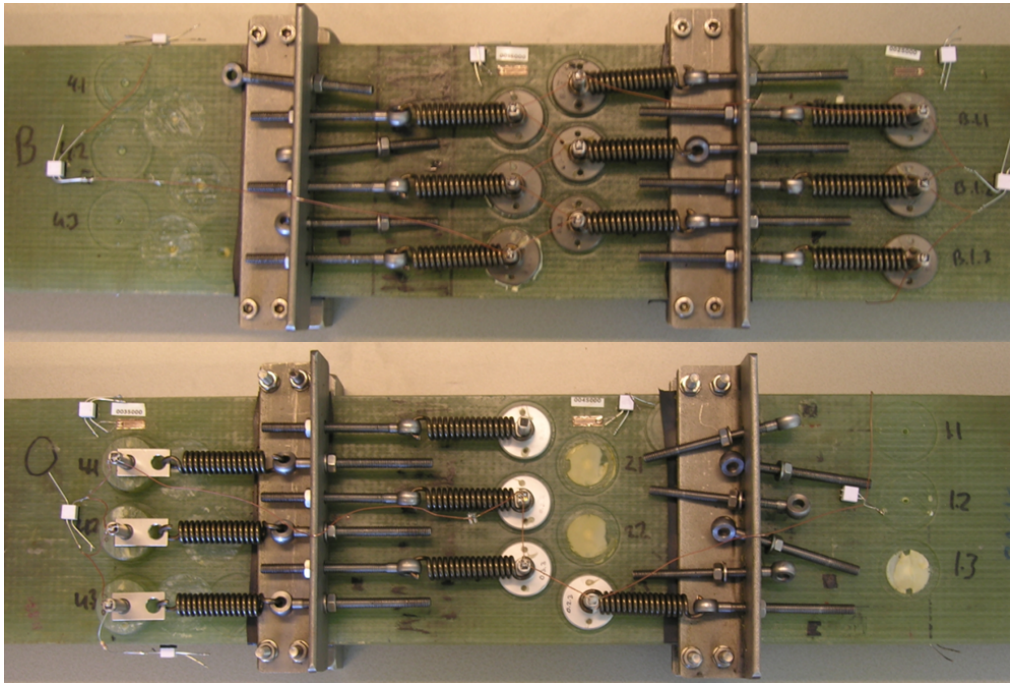


Sensor assembly with housing

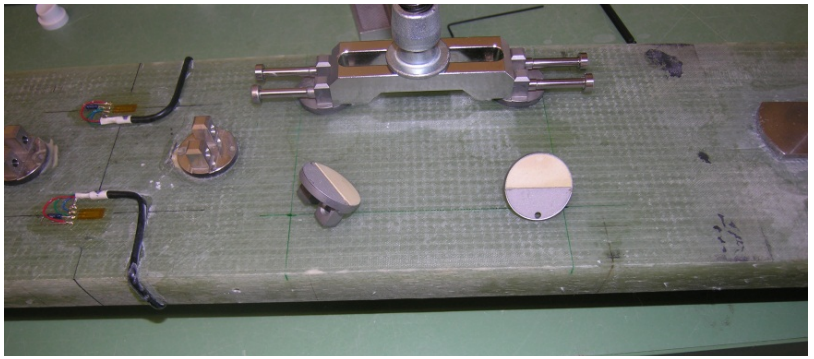


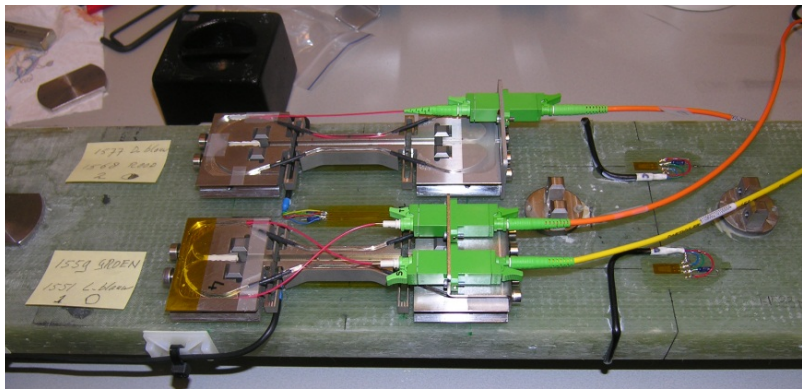
Tool for mounting studs

FOBM: Sensor development



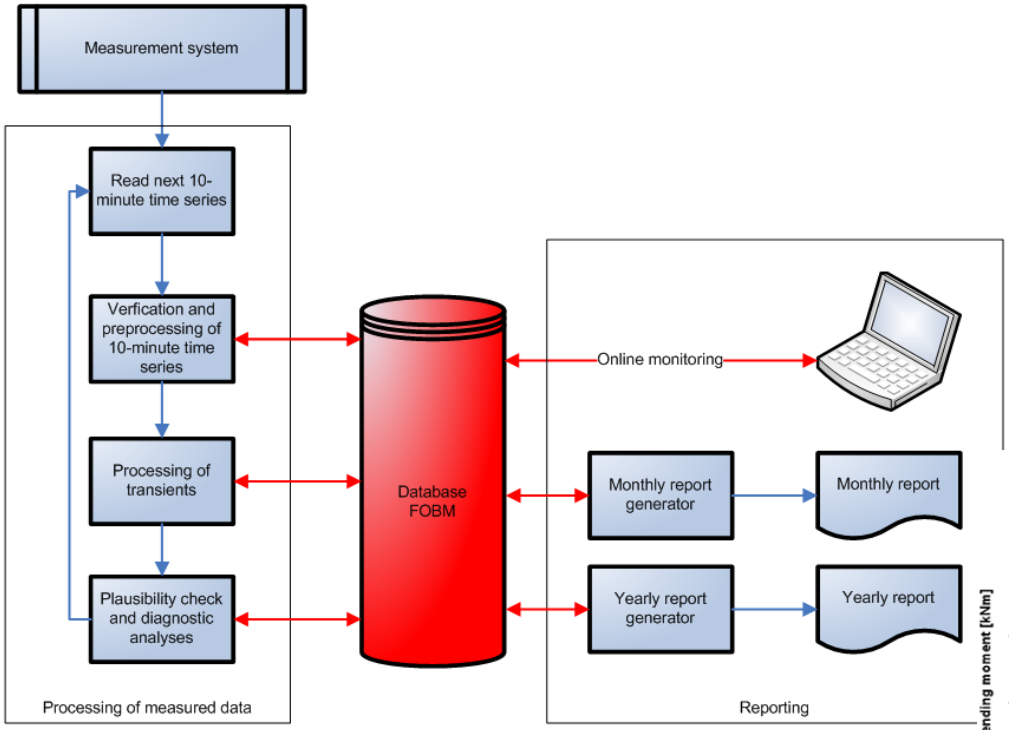
Test rig to verify different bondings between blade and stud



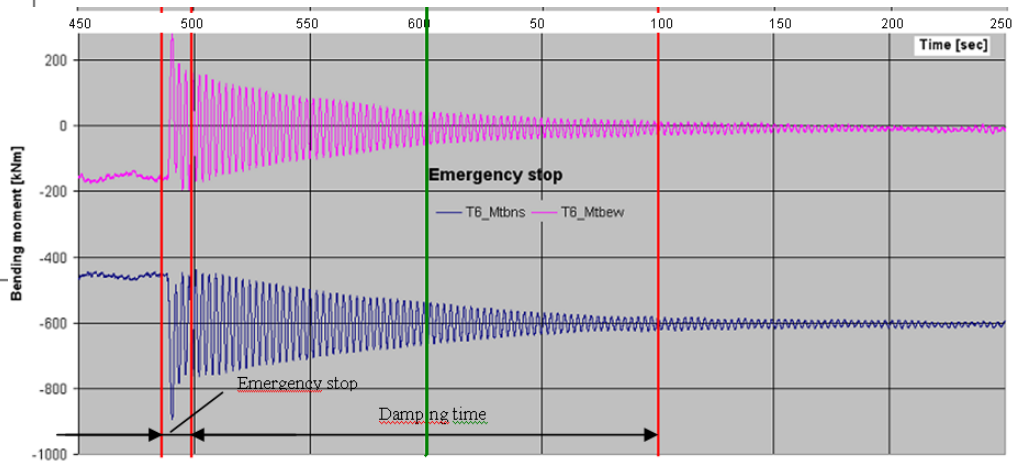


Comparison between optical and electrical strain measurements

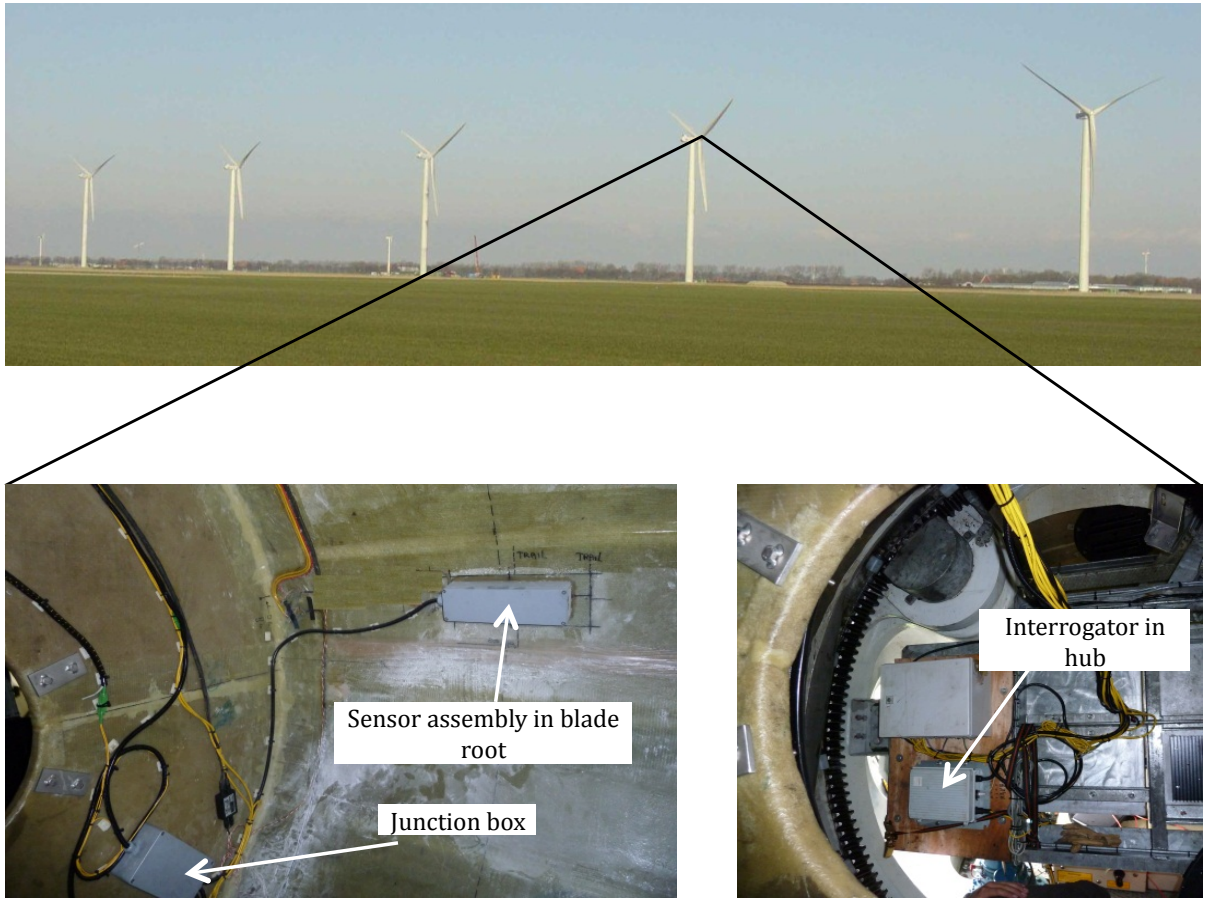
FOBM: Software development



- Automatic checks and validation
- Turbine PLC data as input
- Single mode files vs. 10 min time series
- Reporting for O&M optimisation
- Input for FleetLeader software



FOBM: Field experiments

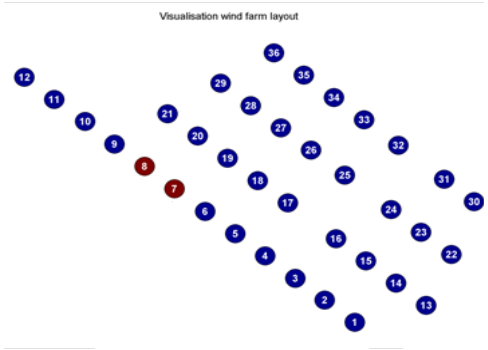


Status

- Field tests at XEMC-Darwind turbine (Feb 2014 – June 2014)
- System ready for industrialisation
- Investigations for control and IPC purposes just started
  - MTBF of interrogator and sensors?
  - Redundancy / more sensors?
- FOBM system as part of ECN's program on low cost load monitoring and reduction of O&M costs

Low-cost wind farm load monitoring: FleetLeader

FleetLeader: Concept



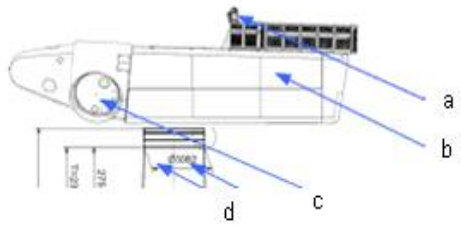
1) Wind farm with loads data of two FleetLeaders and SCADA data of all turbines

FleetLeader: Implementation

- FleetLeader is currently implemented in Sheringham Shoal wind farm
- Show that the FleetLeader concept can be used to influence and steer O&M decisions in a large offshore wind farm:
  - Maintenance can be performed according to the actual condition (expected remaining lifetime) of the different wind turbine components
  - This approach contributes to lowering the O&M costs
- Project work packages:
  - WP 1: Measurement infrastructure
  - WP 2: Development of knowledge for O&M optimisation
  - WP 3: Development of the Fleet Leader software
  - WP 4: Endurance test

FleetLeader: Measurements

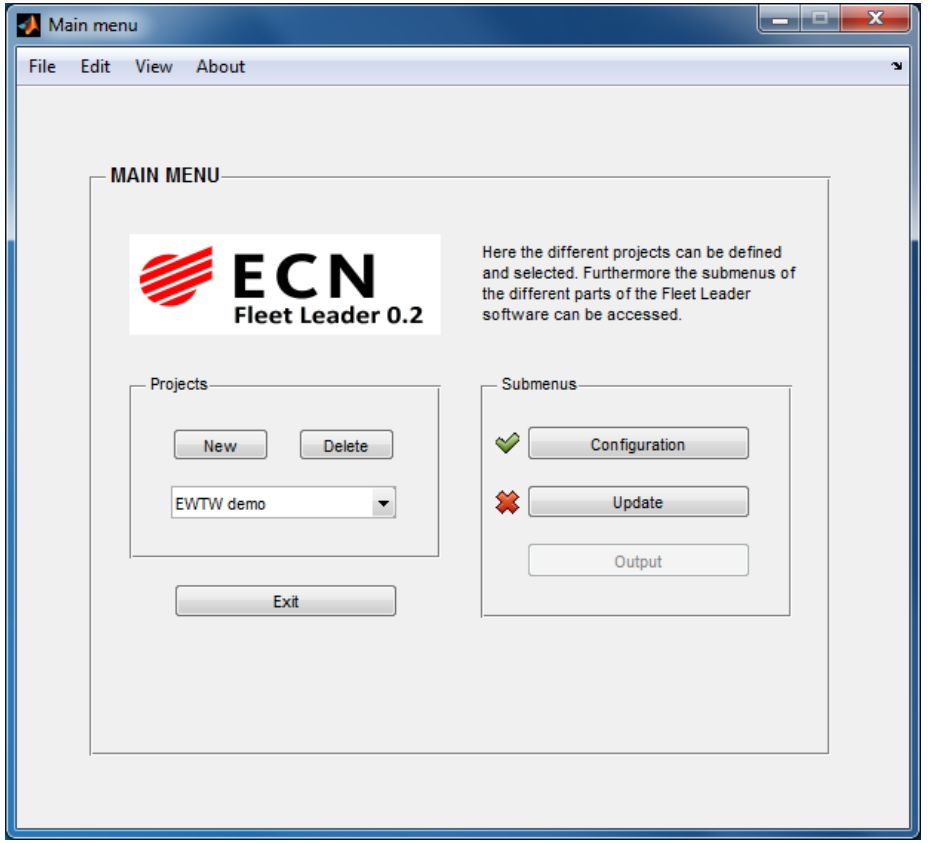
- Two turbines instrumented with load measurements in blades, tower and support structure.
- Fastlog data from all 88 turbines.
- First data received January 2014.
- Measurement campaign will run for at least two years.



Sheringham Shoal
by Scira Offshore Energy

FleetLeader: Software

- Software ready for application
- Receives load measurements from 2 turbines and SCADA data from 88 turbines.
- Procedure:
  1. Receive data
  2. Categorise data w.r.t. operational mode and wake condition
  3. Establish relations between loads and SCADA signals
  4. Predict loads at all turbines
  5. Compare and rank turbines w.r.t. loads.



FleetLeader: Evaluation

- Every month new Sheringham Shoal data are received.
- Analysis with Fleet Leader software.
- Report with predicted loads at all turbines.
- Discussion with Statoil/Scira on results and evaluate how information can be used for making O&M decisions.
- Statoil/Scira is responsible for unscheduled maintenance!

Summary

- Introduction
  - Currently O&M cost are high → move to predictive maintenance
  - Combine condition monitoring with load monitoring
- FOBM
  - Reliable measurement hardware & software suitable for long-term offshore application
  - Ready for field tests → system ready for industrialisation!
- FleetLeader
  - Approach for wind farm load monitoring at low costs
  - Currently implemented in Sheringham Shoal wind farm
  - Aim: Demonstrate added value to owner/operator of the farm
- Combined approach offers benefits:
  - Prevent consequence damage (replace before catastrophic failure occurs)
  - Resource optimisation (prioritise based on health/loads)
  - Root cause analysis (understand why certain turbines failed and others not)
  - Lifetime extension / repowering (value of assets after 20 years of operation)