Increasing wind farm profit through integrated condition monitoring and control

Principal Engineer Berit Floor Lund, Dr.ing.
Kongsberg Renewables Technology
Outline

1. Kongsberg Renewables Technology
2. Kongsberg EmPower
3. «Integrated»— not just a buzzword.
At its core, KONGSBERG integrates advanced technologies into complete solutions

Key core capabilities

- Integrating sensors and software
- Supporting human decision making, precision, safety, security
- Cybernetics, software, signal processing and system engineering
- Project and supplier management
Focus on technology leadership forms the basis for our international growth

Global Top 3
- Offshore, merchant shipping applications
- Defence systems and applications
- Niche oil and gas and subsea technologies
- Niche space technologies

Company data (2014 figures)
- 7 726 employees
- 76% revenues from outside Norway
- More than 25 countries
International high-tech solutions, from deep sea to outer space

Advanced solutions and applications for the maritime, oil & gas, renewable wind, defence and space industry.

- Extreme Performance for Extreme Conditions -
World Wide Life Cycle Support

• KM - equipment on more than 17 000 vessels – comprehensive service network

• KONGSBERG’s life cycle services is a **key differentiator in the market**

Kongsberg Maritime’s “follow the sun” support centers, located in Norway, Singapore and New Orleans, ensure service 24/7 around the globe
Kongsberg Renewables Technology

(Innovation – Execution – Acquisition)

• 2010: Kongsberg Maritime (KM Trondheim) activities linked to NCE Instrumentation. Participation in NowiTech, Wind Cluster Mid-Norway.

• 2011: RCN project WindSense. Seminar held by «EcoSystem» on «Operation and maintenance of offshore wind turbines»

• 2012: Kongsberg hires InTurbine/Scandinavian Wind as consultants

• 2012: Strategic decision to enter wind power market and establish a department for this at KM Trondheim, 4 persons employed.

• 2012: Kongsberg aquires InTurbine (4 persons)

• 2013: Development of new product starts.

• 2013: Support from Innovation Norway, Miljøteknologiordningen

• 2014: 14 persons + consultants

• 2015: From Kongsberg Maritime to Kongsberg Renewables Technology


• 2015: First contract on Kongsberg EmPower, June 2015.

The KONGSBERG ambition

- **Reduced O&M costs** — through improved overview and improved negotiation position

- **Yield optimization** — through increased production time and decreased wake issues

- **Reduced downtime** — through understanding the challenges in your wind farm

Kongsberg EmPower  Objective: 5-8% reduction in CoE
Common challenges for wind farm owners

• Often no access to primary turbine signals, only aggregated values delivered by turbine manufacturer to wind farm owner.

• Difficult to extract valuable information from primary signals (multivariable, dynamic relationships)

• Different turbine types—different systems

• Different functionality – different systems with no/little integration
Kongsberg EmPower
- One portfolio, one system
Kongsberg EmPower
- Smart monitoring & control of wind farms

- **Conditioning Monitoring** with enhanced analysis of turbine data
- **Production Forecasting** through improved weather analysing tools/ algorithms
- **Wind Farm Control** reducing wake and turbine loads with dynamic production optimizer
- **Performance Monitoring**: reporting, fault analysis, trending and benchmarking of wind turbines and wind farms

Production optimizer, load and wake control

Reduced down time and operational cost

Reduced imbalance Improved maintenance planning

Identify deviations Improved benchmarking

Potential of 5-8% reduction in CoE
Kongsberg EmPower – Wind Farm Control

*Increased yield – reduced operating costs*
Production Forecasting

- Correction of weather forecast based on historic data
- Correction based on wind observations
- Production forecasting based on several methods, taking turbine states, site specific issues, grid condition, and maintenance plans into consideration.
Kongsberg EmPower
Performance monitoring, farm level.
Kongsberg EmPower Turbine view, condition monitoring.

- **Condition Monitoring**
  - Early detection of failure
  - Advanced analysis methods of
    - Scada signals
    - Add-on sensors
  - Failure classification - RUL estimation
  - CM results used by many other EmPower modules
Virtual («soft») sensors help interpreting multivariable, dynamic relationships
«Friction» in same type of bearing, all turbines.
Developing bearing wear

- Model (ANN) temperature deviation and vibration – same trend.

- RMS vibration – increasing trend
Failure Model of Rolling Element Bearing

• Stage 1
  – Noise level normal
  – Temperature normal
  – Earliest indications in the ultrasonic range (35000 Hz)

• Stage 2
  – Slight increase in noise level
  – Temperature normal
  – Slight bearing defects begin to excite natural frequencies of bearing components (500 to 2000 Hz).

• Stage 3
  – Noise level quite audible
  – Slight increase in temperature
  – Bearing frequencies with harmonics and sidebands (BPFI, BPFO, 2xBSF and FTF) clearly visible in linear scale with a noticeable increase in floor noise.

• Stage 4
  – High level of audible noise
  – Significant temperature increase
  – Discreet bearing defect frequencies disappear and are replaced by random broad band vibration in the form of a noise floor
Why condition monitoring?

- **Cost** of planned repair is < 30% of unplanned replacement (DEWI report, onshore)

  +

- **Lost Production** (time and timing)
  - Component lead-time
  - Waiting for vessel and personnel availability
  - Waiting for weather
  - Transport to farm
  - Enter Turbine
  - Perform repair
  - Exit Turbine

![Yearly Production graph](image)

Sheringham Shoal data collected from the web
Kongsberg EmPower, integration

External results/signals

Kongsberg EmPower

WFC

P. Forec.

CM

PM

Many common methods and models
Condition and production based maintenance

- EmPower Production Forecast
  - Request timeslot for maintenance
  - Time-slots for maintenance
  - Remaining useful lifetime
- EmPower Condition Monitoring
  - Changed component

- Maintenance management system
  - Request resources
  - Available resources
  - Maintenance schedules
- Asset management system
  - Available resources
Maximizing performance by providing THE FULL PICTURE

Berit Floor Lund, Dr.Ing.
Principal Engineer
Wind Farm Management Systems
Kongsberg Renewables Technology AS
Haakon VII’s gate 4
N-7041 Trondheim, Norway

Mobile phone: +47 9305 9302
Switchboard: +47 815 73 700
berit.floor.lund@kongsberg.com

WORLD CLASS – through people, technology and dedication