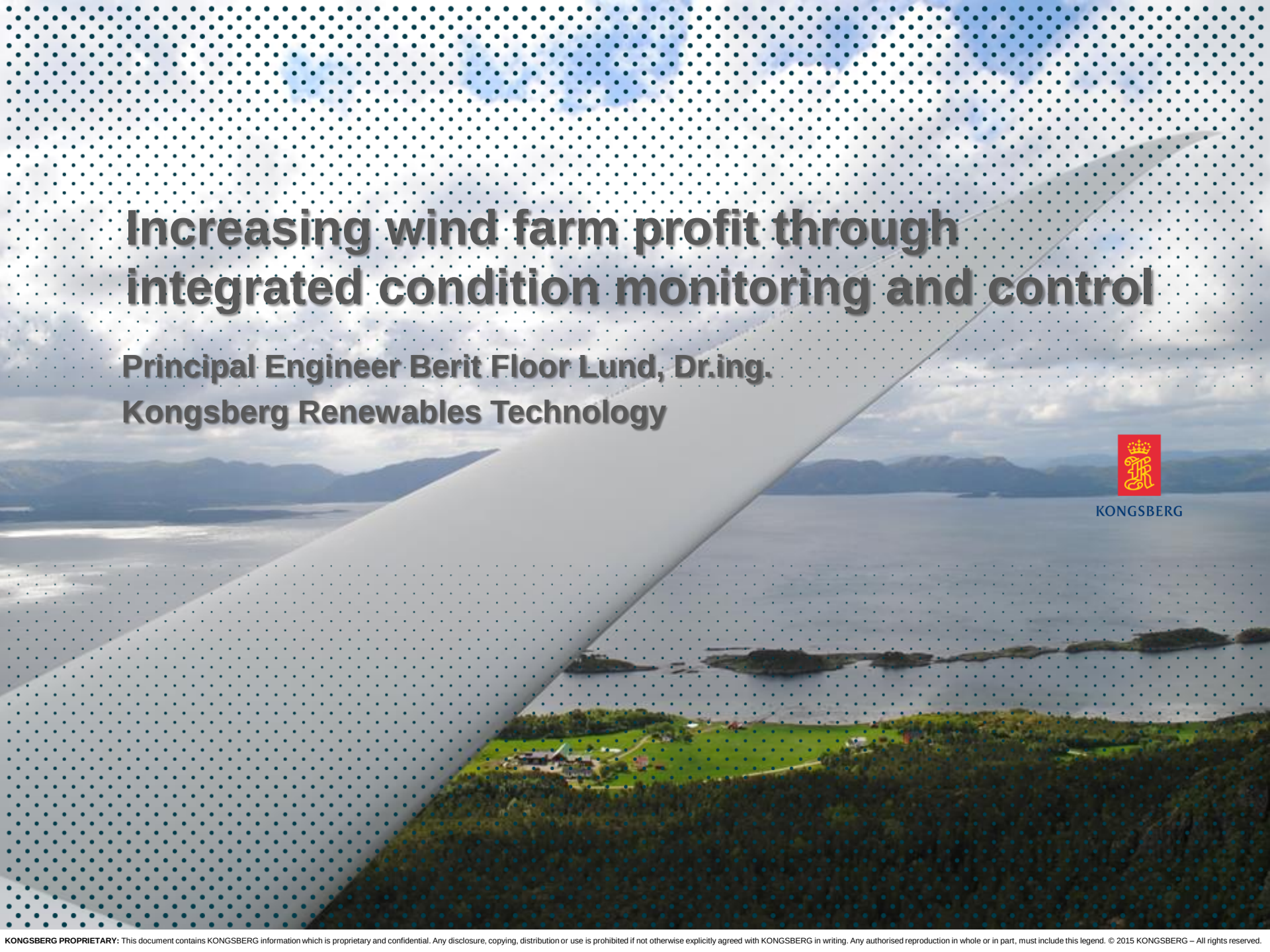
Increasing wind farm profit through integrated condition monitoring and control

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



KONGSBERG

Outline

1. Kongsberg Renewables Technology
2. Kongsberg EmPower
3. «Integrated»– not just a buzzword.

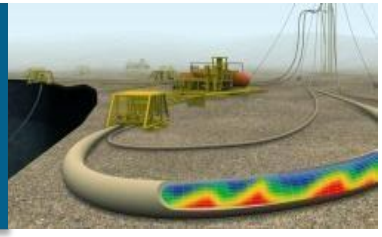
At its core, KONGSBERG integrates advanced technologies into complete solutions

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

Dynamic positioning and vessel automation

Real time drilling support



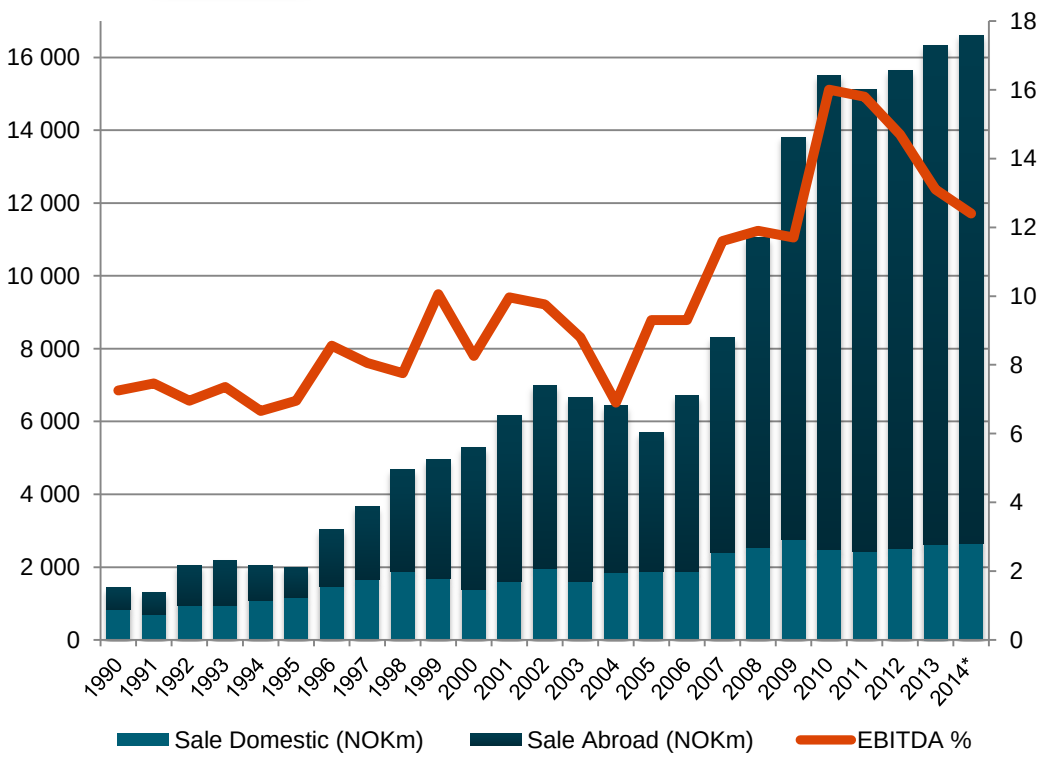
Advanced robots

Command and control systems

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

KONGSBERG

(Innovation – Execution – Acquisition)

TIMELINE

- **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**: Official product launch June 15, 2015.
- **2015: First contract on Kongsberg EmPower, June 2015.**

http://www.kongsberg.com/en/kongsberg-renewables/news/2015/june/arctic-wind-chooses-kongsberg-empower/

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**

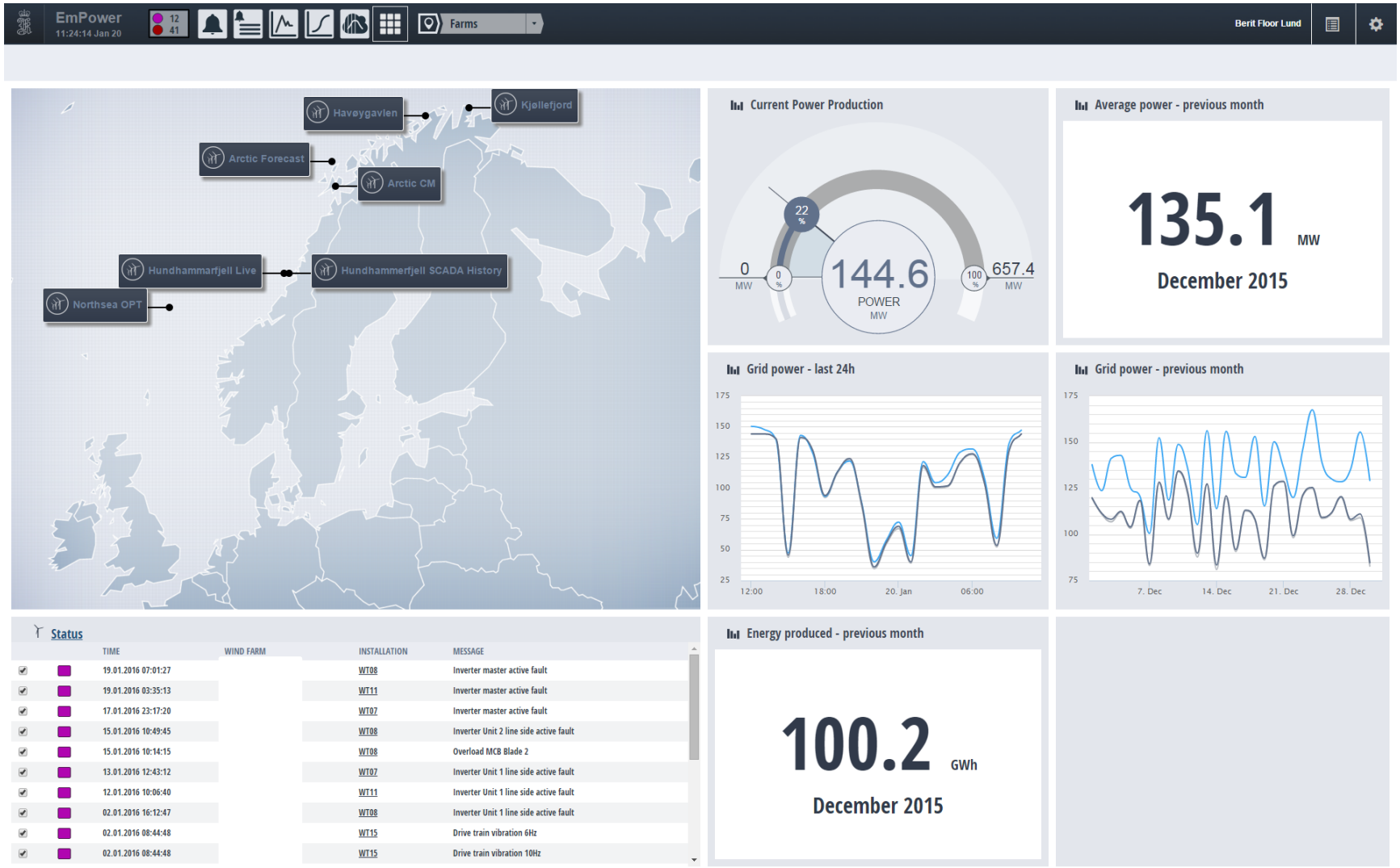
Common challenges for wind farm owners

- 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

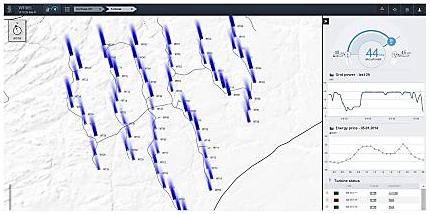
KONGSBERG



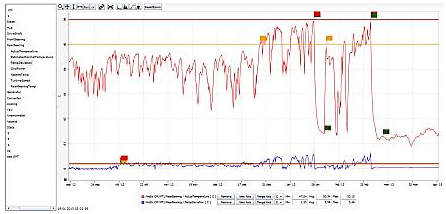
Kongsberg EmPower

-Smart monitoring & control of wind farms

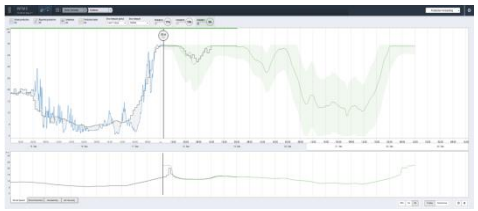
- **Conditioning Monitoring** with enhanced analysis of turbine data
- **Production Forecasting** through improved weather analysing tools/ algorithms
- **Wind Farm Control** reducing wake and turbine loads with dynamic production optimizer
- **Performance Monitoring;** reporting, fault analysis, trending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



Production optimizer, load and wake control



Reduced down time and operational cost



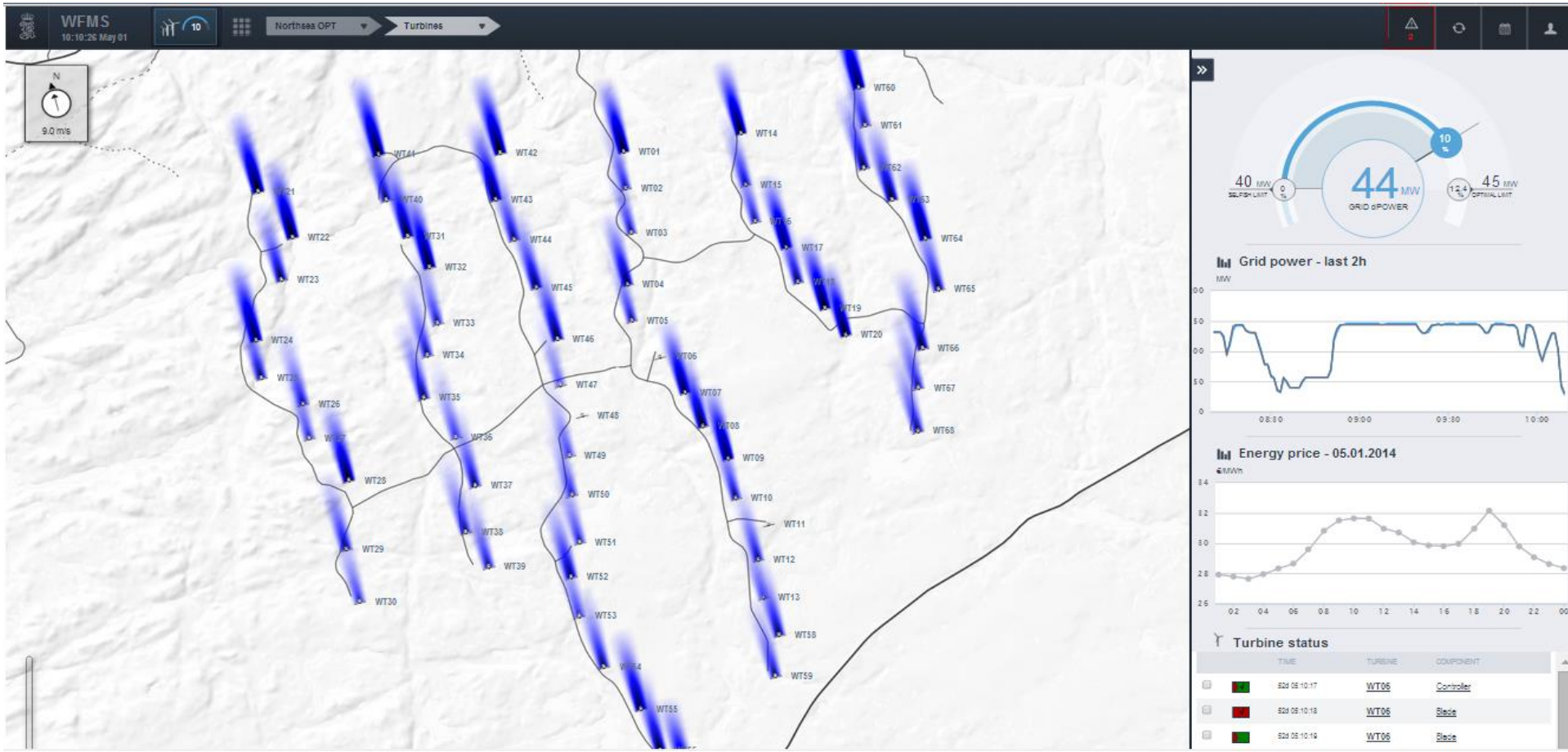
Reduced imbalance Improved maintenance planning

Identify deviations Improved benchmarking

Potential of 5-8% reduction in CoE

Kongsberg EmPower – Wind Farm Control

Increased yield – reduced operating costs

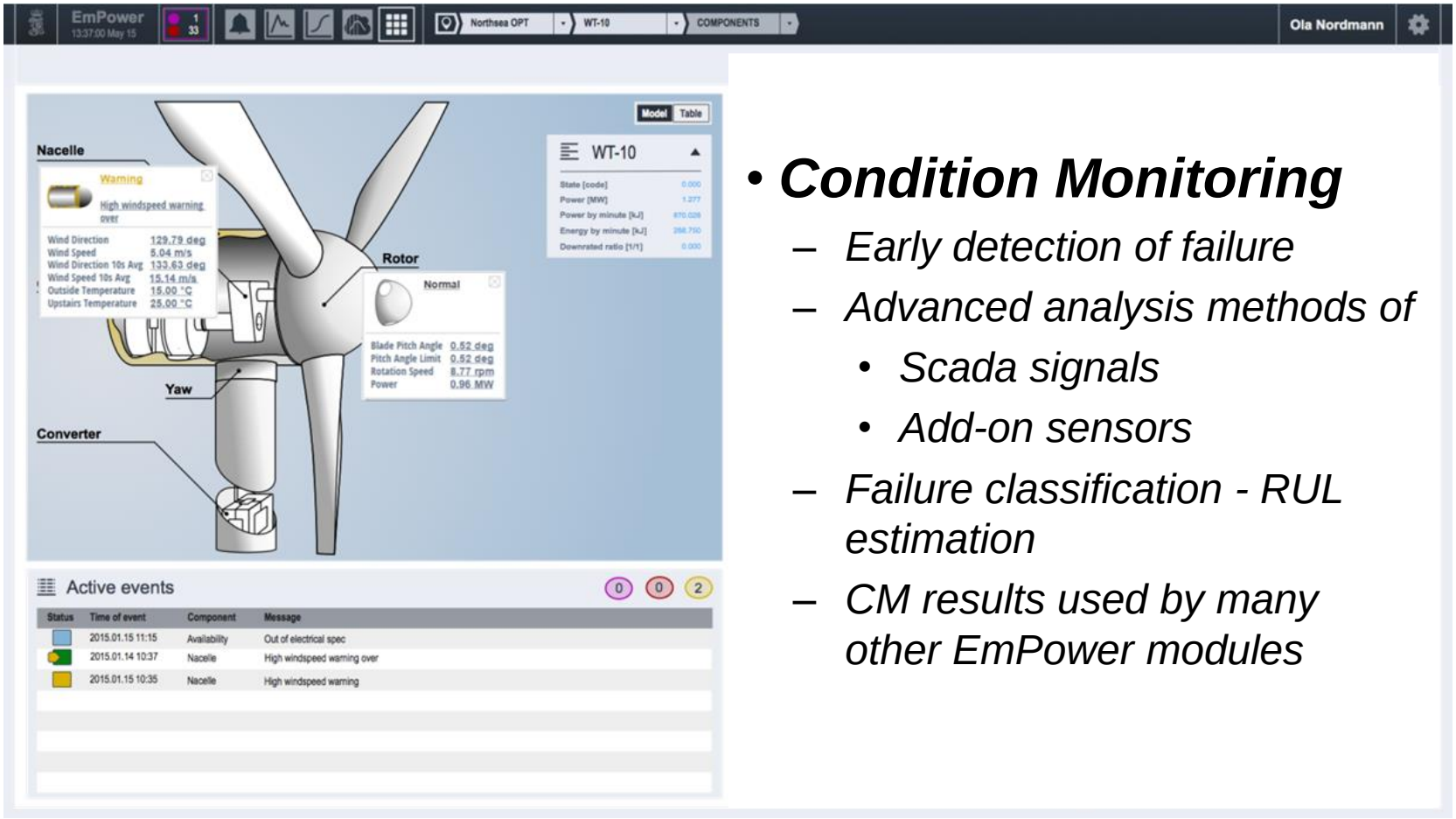


Production Forecasting

- *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 condititon, and maintenance plans into consideration.*

Kongsberg EmPower
Performance monitoring, farm level.

Kongsberg EmPower
Turbine view, condition monitoring.



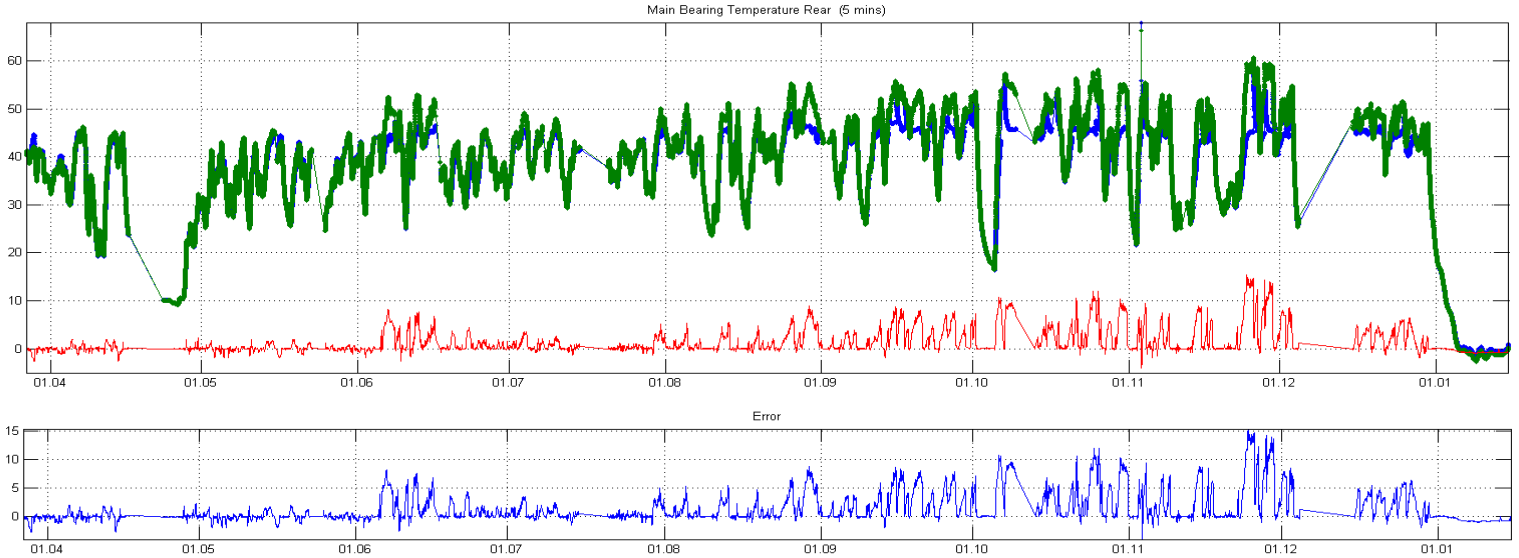
- ***Condition Monitoring***
  - *Early detection of failure*
  - *Advanced analysis methods of*
    - *Scada signals*
    - *Add-on sensors*
  - *Failure classification - RUL estimation*
  - *CM results used by many other EmPower modules*

Virtual («soft») sensors help interpreting multivariable, dynamic relationships

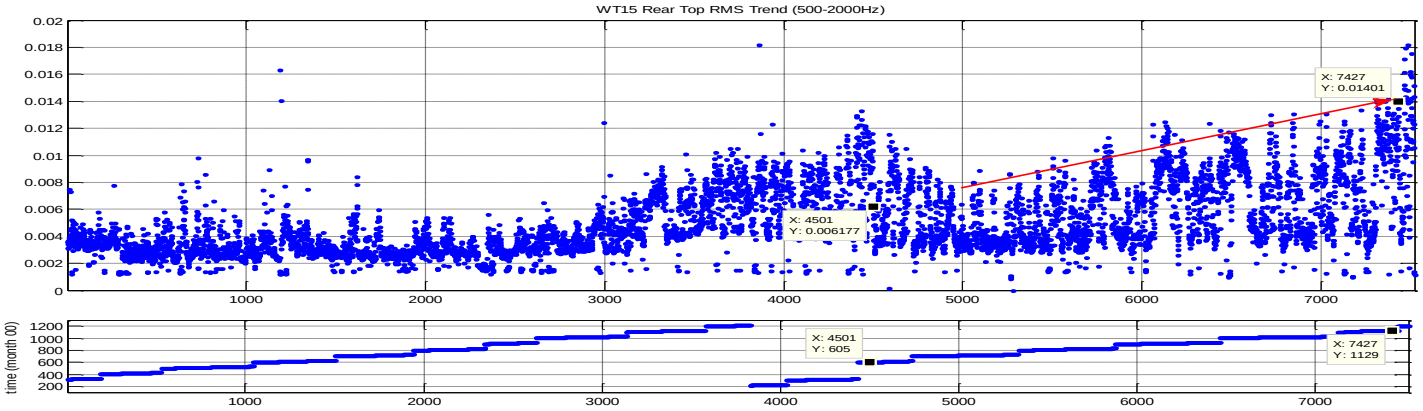
«Friction» in same type of bearing, all turbines.

Developing bearing wear

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



- RMS vibration – increasing trend



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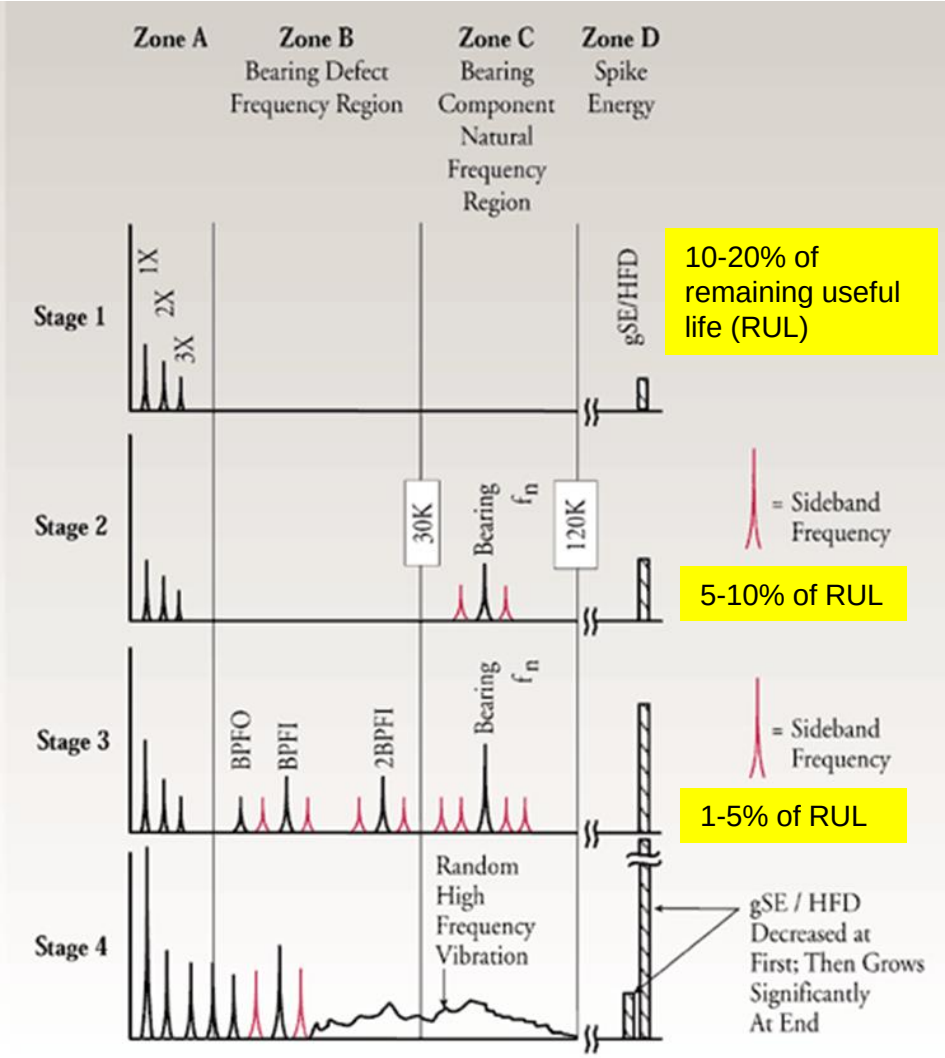
Page 18

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?

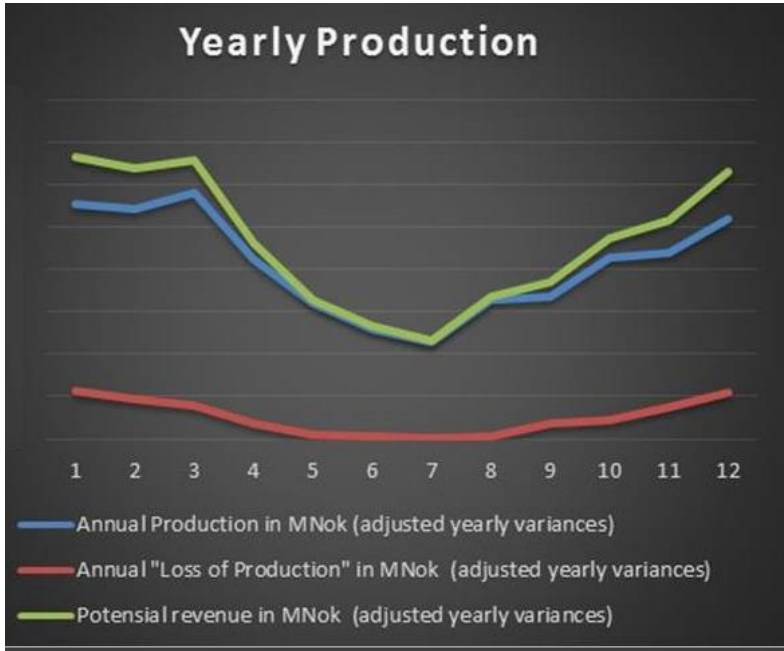
- **Cost** of <u>planned</u> repair is **< 30%** of <u>unplanned</u> replacement (DEWI report, onshore)

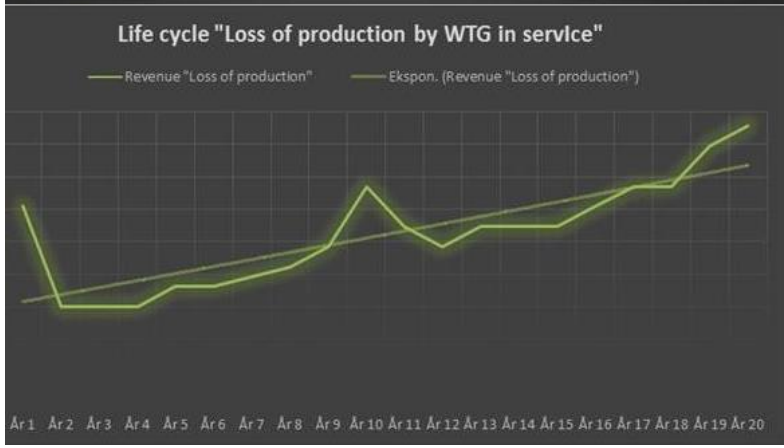
  +

- **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

Planned

Corrective



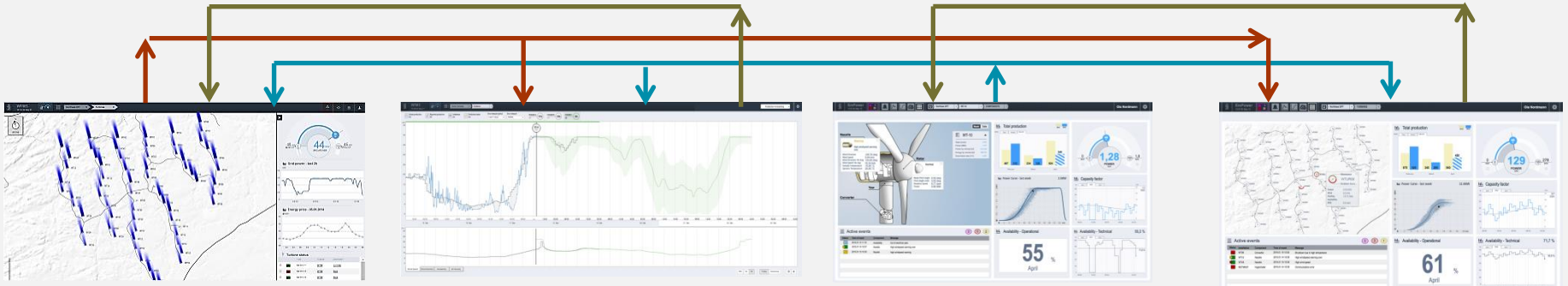


Sheringham Shoal data collected from the web

Kongsberg EmPower, integration

External results/signals

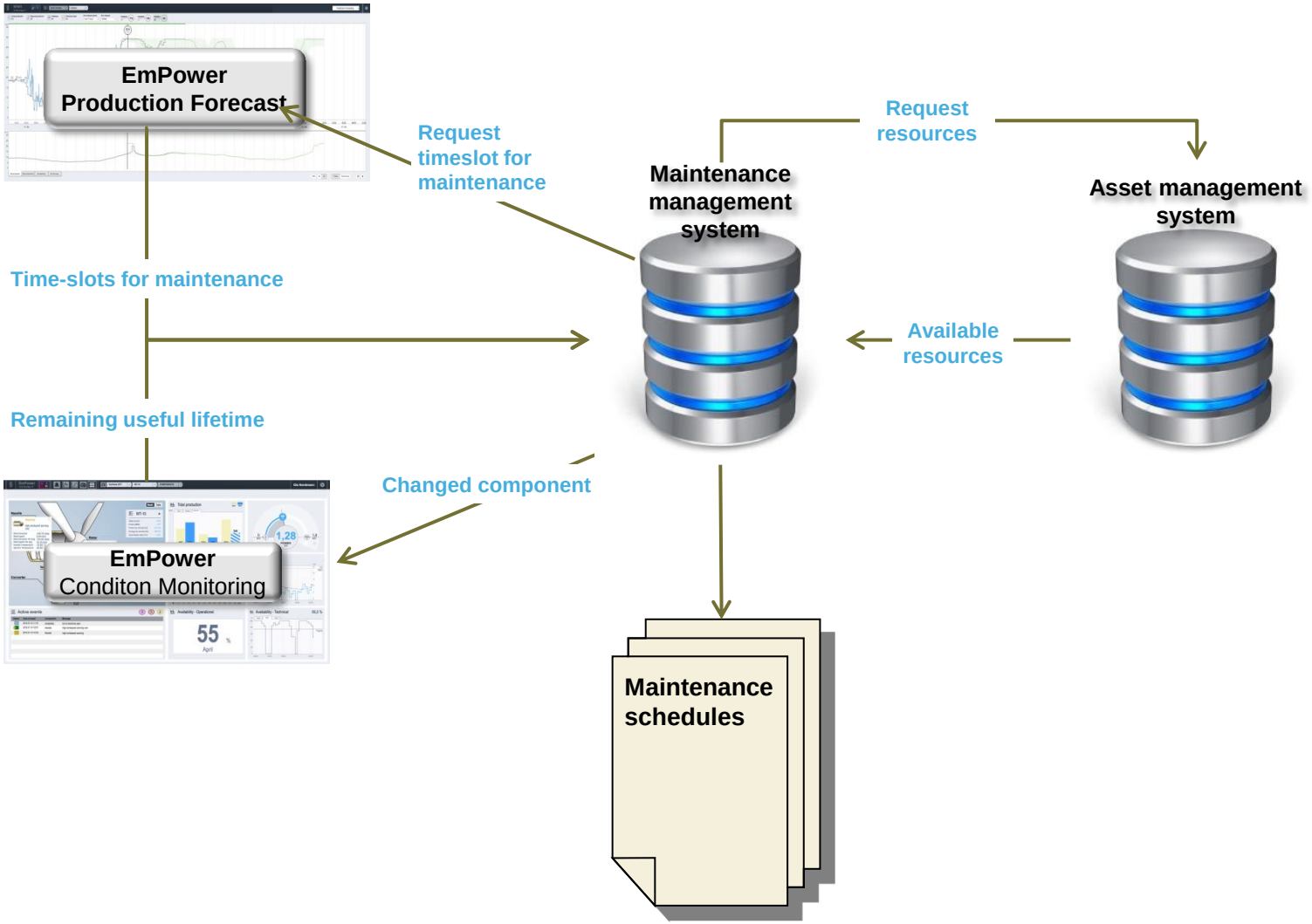
Kongsberg EmPower



WFC | P. Forec. | CM | PM

Many common methods and models

Condition and production based maintenance



Maximizing performance by providing THE FULL PICTURE

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