Predictive Maintenance in the wind turbine industry

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WHAT WE DO – Core business & products

VALUE CHAIN. MORE THAN A MANUFACTURER.

PROJECT DEVELOPMENT

- Selection of location
- Ownership
- Optimal siting
- Wind measurements
- Soil survey
- Sound / shade emission
- Economic viability
- Grid connection
- Special purpose registration
- Environmental permitting
- Building permitting

TURBINE DELIVERY

CIVIL WORKS

ELECTRICAL INFRASTRUCTURE

INSTALLATION & COMMISSIONING

SERVICE

Project Development, Marketing, Financing

- Leading company in France
- Active also in India

Wind Farm System Planning

- Review customer micro-site planning
- Support customers (co-development) to receive approvals and to optimise park layouts

Production and Technical Implementation

- Assemble WTG
- Produce selected components (blades, control systems)
- Install onsite
- Carry out initial operation

Wind Farm Operations

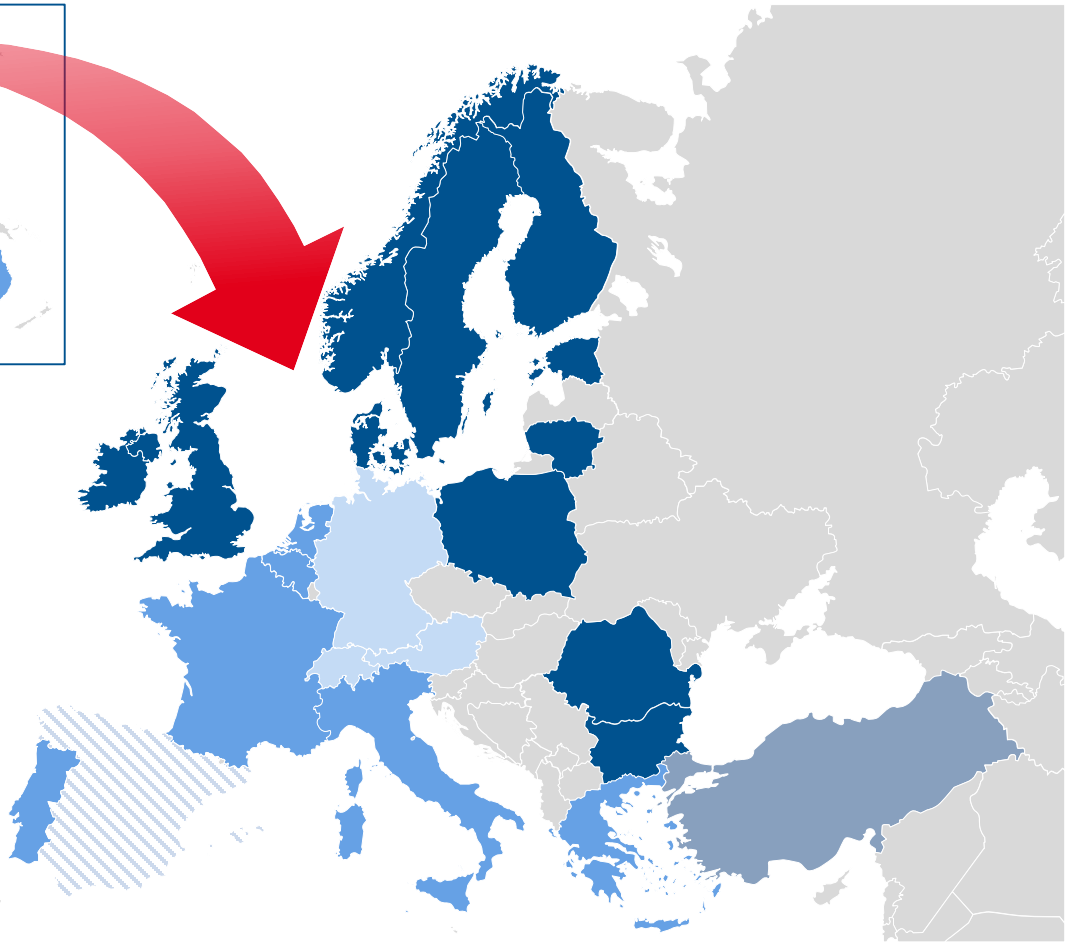
- Offer additional services: increased demand due to new wind farm investors interested in stable cash flows

Services and Maintenance

- Provide high quality service to minimize downtime and maximize yield

WHERE WE ARE – Fleet under Service Contract

AS OF 2018 NORDEX HAS 17 GW OF TURBINES UNDER SERVICE CONTRACT GLOBALLY



Division Europe **12 GW**

- Region North: 3.6 GW
- Region DACH: 3.4 GW
- Region Mediterranean: 2.9 GW
- Region Turkey / Mid. East: 2.1 GW

WHERE WE WORK – Examples

THE SITES ARE TYPICALLY REMOTE AND OFTEN WITH CHALLENGING ACCESS

At Nordex, safety is what matters

SAFETY + LOW COST / KWH + PREDICTABLE PRODUCTION MATTER

Safety

Cost / kWh

- *Cost driver examples*
  - # of interventions
  - Unexpected major component failures
    - Crane @ spot market price
    - No access due to weather conditions
    - No transport permission
    - Part not available
- *Always*
  - 24h a day
  - 365 hours a year
  - 25 years or more
  - Upgrades

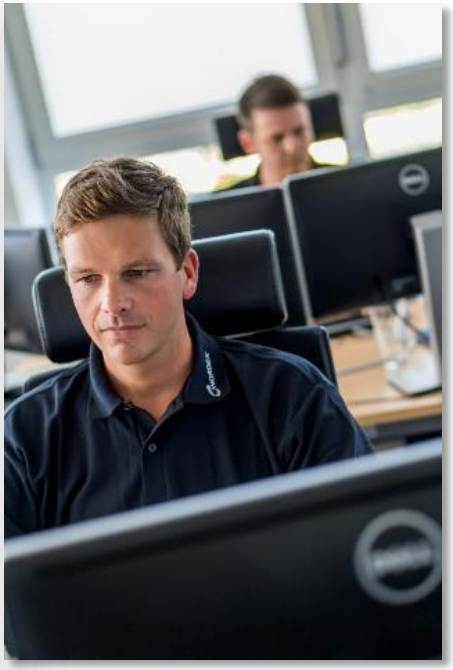
Predictable Production

- No wind → No lost production
- Energy price = 0 → No lost production

„Normal" Remote Monitoring

REACTIVE REMOTE MONITORING HAS BEEN STATE OF THE ART FOR MANY YEARS TO MAXIMIZE AVAILABILITY AND MINIMIZE SITE INTERVENTIONS

- 24/7 Monitoring
- Remote diagnostics/ root cause analysis and fault correction
- Providing possible solutions for fault remedy and preventive maintenance information in order to reduce downtime
- Weekend Dispatching
- Scheduled start/stop



PREDICTIVE MAINTENANCE BRINGS US TO THE NEXT LEVEL

My definition of predictive maintenance

WHAT DO I ACTUALLY MEAN BY „PREDICTIVE MAINTENANCE"?

Reactive → **Preventive** → **Condition based** → **Predictive**

React after the failure has occurred

(e.g. drive to turbine when it stopped due to a broken hydraulic pump and exchange it)

Act before a potential failure

(e.g. exchange hydraulic pump motors every 5 years, independent of their condition)

Exchange a component based on actual condition

(e.g. annually inspect slip ring brushes and exchange when required)

Act based on a computer model that can predict component failure / remaining useful life

(e.g. exchange the hydraulic pump because a computer model says it will fail within the next 3 months)

Two Approaches for predictive maintenance

BOTH APPROACHES ARE COMPLEMENTARY AND COVER MOST FAILURE MODES

APPROACH

1 PREDICTIVE MONITORS

DATA USED

SCADA data, e.g.,
- wind speed and a direction
- rotor shaft speed
- gearbox oil temperature
- generator voltages
- pitch angle
- yaw movements

METHODS

- State-of-the-art artificial intelligence algorithms to model normal component behavior
- Impending failures are predicted as deviation from normal behavior

2 CONDITION-MONITORING SYSTEMS (CMS)

DATA USED

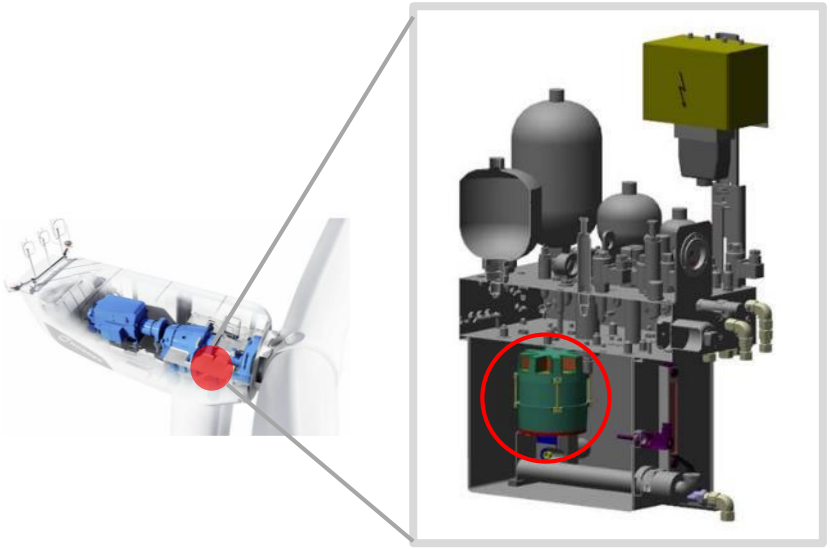
Vibration data from sensors, e.g.,
- Time signal from vibration sensors
- Spectrum data (Acceleration, Velocity, Displacement)

METHODS

- Trend analysis
- Signal analysis (time and spectrum)

Abnormally high vibrations are indicative of impending failures.

Example – Hydraulic pump failure prediction



Hydraulic oil pump unit

Purpose	› Build pressure to operate rotor and yaw brakes
Normal operation	› Runs ~300 times per day; **5 seconds cycle runtime** › Some seasonal deviation
Failure	› Upward trend in cycle runtime ➔ **Pump to be exchanged**

KEY FACTS

- Undetected pump issue results to entire hydraulic unit failure
- Our detection method prevents this secondary damage
- Cost of pump: ~$400
- Cost of unit: ~$5000

Operational process is key to success

ALIGNED OPERATIONAL PROCESS CONVERTS PREDICTIONS INTO ACTIONS

Predictive models raise alert when abnormal behaviour is detected

Alert registered into **incident management tool**

Expert data analysts validate **alert**

Work order **planning** and **preparation** begins

Technician carry necessary equipment **to the turbine and resolve the issue**

Future of predictive maintenance in wind industry

MINIMAL SCHEDULED MAINTENANCE; MAXIMAL PREDICTIVE MAINTENANCE

Technical Innovation

Continue innovation to be able to predict every failure mode

- **Additional sensors**
  More sensors in new turbines for more analytics. E.g., for our latest turbine, we can calculate dynamic loads on drive train by continuously reading drive train speed and acceleration
- **IoT platforms**
  IoT platforms enhance real-time interaction with turbine. Opens new opportunities, e.g., monitoring electrical components to reduce maintenance costs
- **Image analysis**
  Automated analysis of thermal and surface images of blades, tower, and other components will offer big cost-saving opportunities

Operational Excellence

Use alerts to optimize onsite operations and support departments

- **Minimize site interventions**
  No unplanned maintenance and minimal scheduled maintenance
- **Optimize managing spares**
  Use lead time for better pricing for spares from suppliers and availability on site
- **Smart dispatching**
  Apply AI algorithms on enterprise data to optimally schedule work orders and team assignments

Summary

- Wind industry is **moving towards predictive maintenance**
- Predictive monitors are capable to significantly **reduce OPEX** through early indications of failures
- Early failures indications have **positive effects within the organization**; e.g., spares and logistics optimization
- Technological advances will increase opportunities to **predict more types of failures**
- Robust solutions and aligned processes can **deliver competitive advantages**

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Thank you for your attention