Predictive Maintenance in the wind turbine industry

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WHO WE ARE – Key figures 2018

NORDEX IS A LEADING GLOBAL WIND TURBINE MANUFACTURER

SALES

EUR 2.459.1 million

EBITDA

EUR 101.7 million

Free Cash Flow

EUR 44.0 million

Working Capital Ratio

-3.8 %

Headquarter:

Hamburg

New installed capacity

2.522 MW

Employees

5.676

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WHAT WE DO – Core business & products

VALUE CHAIN. MORE THAN A MANUFACTURER.

PROJECT DEVELOPMENT	TURBINE DELIVERY	CIVIL WORKS	ELECTRICAL INFRASTRUCTURE	INSTALLATION & COMMISSIONING	SERVICE

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

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 – Nordex Group production footprint

GOOD GEOGRAPHIC FIT FOR PRODUCTION TO SERVE GLOBAL DEMAND

GERMANY
> Nacelle
> Blade

USA
> Nacelle

MEXICO
> Towers
> Blade

SPAIN
> Nacelle
> Blade

INDIA
> Nacelle
> Towers
> Blade

BRAZIL
> Nacelle
> Towers

CHILE
> Towers

ARGENTINA
> Nacelles
> Towers

SOUTH AFRICA
> Towers

Manufacturing site

WHERE WE ARE – Fleet under Service Contract

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

Division International **5 GW**

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
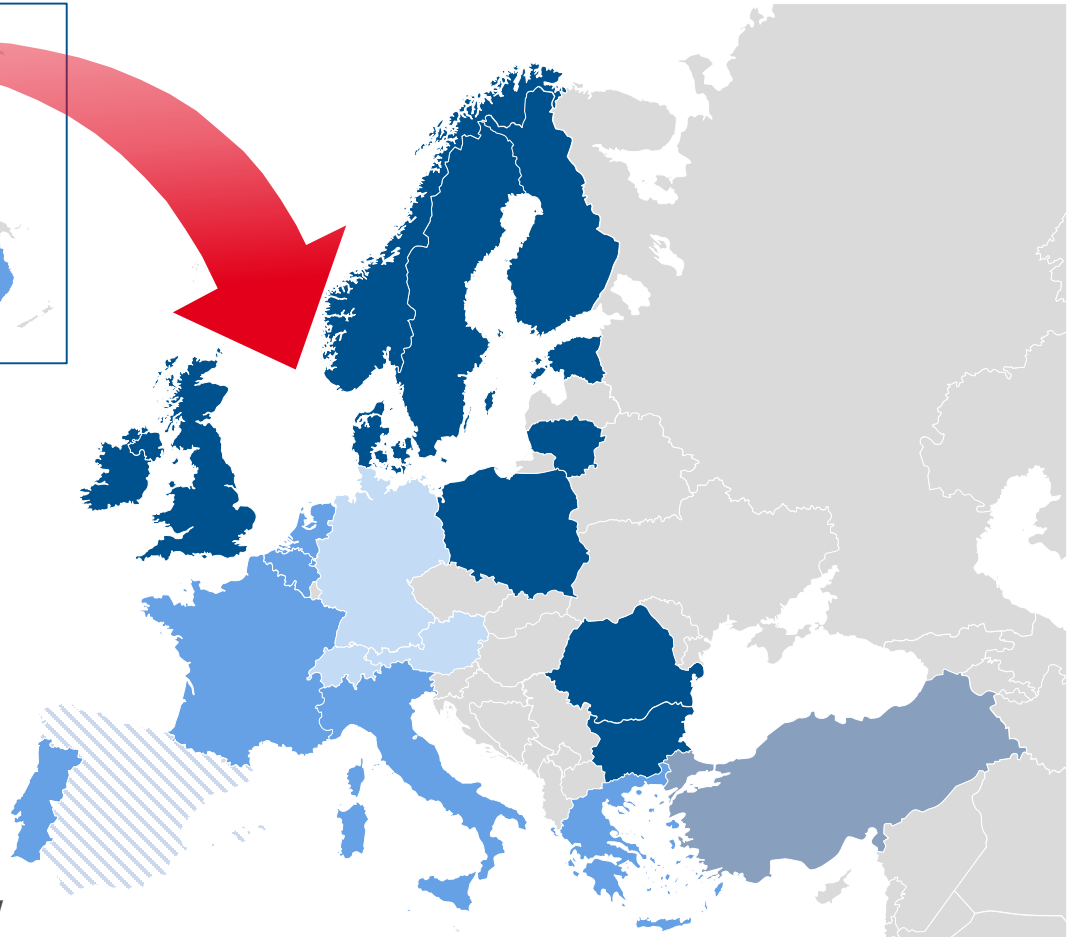
WHAT WE DO IN SERVICE – Typical Service Jobs

SITE WORKS RANGE FROM INSPECTIONS TO MAJOR COMPONENT EXCHANGES

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

> *None-stop Production*
  > 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

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„Normal" Remote Monitoring

REACTIVE REMOTE MONITORING HAS BEEN STATE OF THE ART FOR MANY YEARS TO MAXIMIZE AVAILABILITY AND MINIMIZE SITE INTERVENTIONS
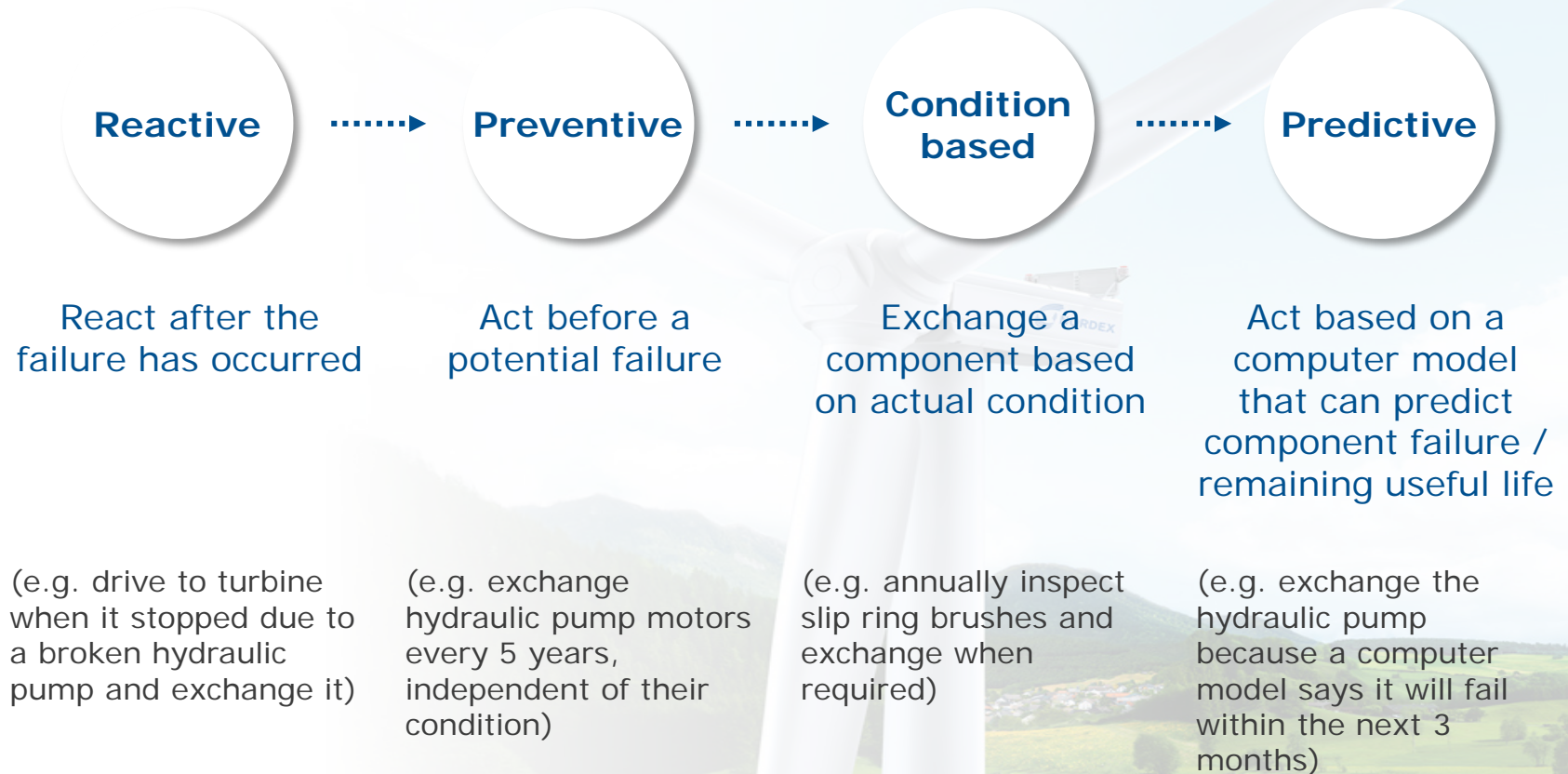
> 24/7 Monitoring

> 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
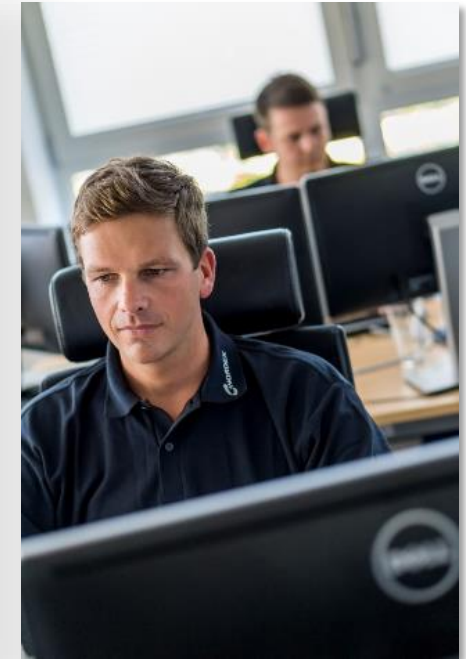
PREDICTIVE MAINTENANCE BRINGS US TO THE NEXT LEVEL

My definition of predictive maintenance

WHAT DO I ACTUALLY MEAN BY „PREDICTIVE MAINTENANCE"?

Reactive ·······► **Preventive** ·······► **Condition based** ·······► **Predictive**

React after the failure has occurred

Act before a potential failure

Exchange a component based on actual condition

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

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

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

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

(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**

2 **CONDITION-MONITORING SYSTEMS (CMS)**

DATA USED	METHODS	DATA USED	METHODS
SCADA data, e.g.,	› State-of-the-art artificial intelligence algorithms to model normal component behavior	Vibration data from sensors, e.g.,	› Trend analysis
› wind speed and a direction		› Time signal from vibration sensors	› Signal analysis (time and spectrum)
› rotor shaft speed		› Spectrum data (Acceleration, Velocity, Displacement)	
› gearbox oil temperature			Abnormally high vibrations are indicative of impending failures.
› generator voltages			
› pitch angle	› Impending failures are predicted as deviation from normal behavior		
› yaw movements			

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Example – Hydraulic pump failure prediction
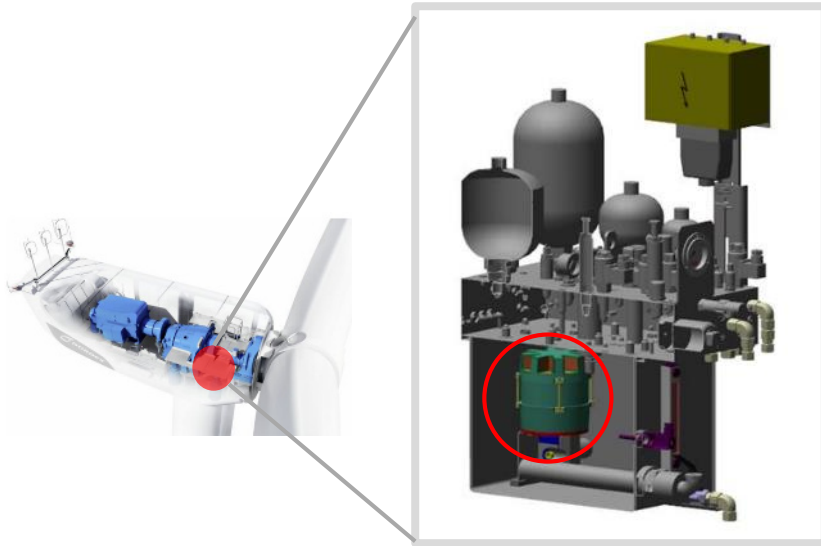
Hydraulic oil pump unit

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

Expected ——
Observed ——

Expected failure day

Pump runtime (in sec)

15

10

5

Jan 2016   Jul 2016   Jan 2017   Jul 2017   Jan 2018

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**

THE FUTURE – Some examples

PREDICTIVE MAINTENANCE IN WIND WILL DEVELOP FURTHER, SOME EXAMPLES / THOUGHTS …

- **Image analysis** (e.g. blade crack propagation)

- **More data** (IoT, more sensors)

- Forecast **remaining component life** through periodic load assessment

More and better predictions

- Continous **replacement** of time based **preventive jobs**

- **Predictive based spare parts planning** not just for selected components

- **Automized job scheduling** based on predicted repairs, expected energy production and power price

Better integration into operations

Summary

› Wind industry is **moving towards more predictive maintenance** because it has the potential to further reduce **cost/kWh**

› **We do it** leveraging:
  › **Skills** (data analysts, operations and specialist engineers)
  › **Standard AI** / machine learning models
  › **Scale** (big fleet under contract)
  › **Solid link** between field operations and central support

› Predictive maintenance is **not the solution to all our challenges**, but an important and exciting part of **future service concepts**

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> **Thank you for your attention**