VENTUS GROUP

Martin Rath
Poul Anker Lübker

14:30

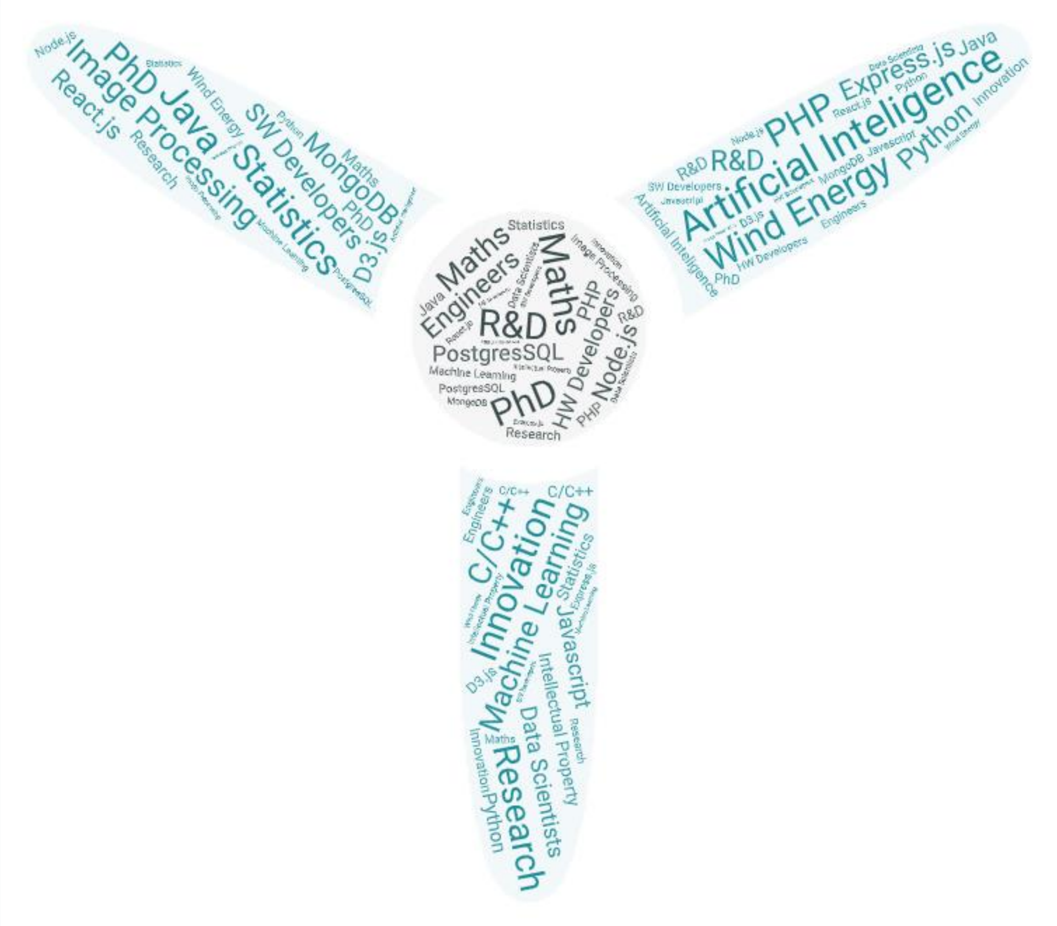
Condition Monitoring – aktuelle Herausforderungen.

St. Pölten 18. Jänner 2022

Kontakt:
mrath@ventus.group
+43 676 340 77 33

ABOUT VENTUS GROUP

- VENTUS GROUP started in 2016
- today more than 50 researchers, engineers, technicians, and data scientists, many coming from the wind turbine industry
- background in math, machine learning, image processing, SW&HW development, and wind energy
- highly dynamic, young, and international team
- 3 PhDs in Math, Machine Learning & Power Electronics
- ISO9001 and ISO 45001 H&S certification process ongoing



VENTUS GROUP - BUSINESS IN WIND ENERGY SECTOR

Ventus Engineering GmbH

- Rotor Monitoring System (TripleCMAS) *patent*
- Monitoring lightning grounding system (LEDS) *patent filed*
- Inspect leading- and tailing edge in operation *patent filed*
- Dynamic Blade Pitch Measurement off-shore *patent filed*
- CTV + gyro platform for off-shore inspections *patent filed*
- Wiederkehrende Prüfung using drones *patent filed*
- Graphene containing carriers for WTG *patent*

R&D

Ventus Wind Services (AT,DK)

- Wind farm BIG data analysis
- Nacelle based LiDAR Measurements
- Dynamic & Static Blade Pitch Measurement *patent*
- Drone Inspections *patent filed*
- Taking-Over & End-of-Warranty Inspections
- Dissolved Gas Analysis
- Wind Farm Optimization & Lifetime Extension
- Ventus academy and service support system

Services & Products

Ventus GmbH

- Extended Warranty
- Construction property damage
- Delay in start-up
- Machinery Breakdown
- Business interruption

Insurance

AGENDA

When the wind industry goes digital

The potential in digitalisation and data:

- Data capture and allowed access to existing raw data
- Data processing and analysis
- The way of managing wind assets fleets in 2030

Example on new technologies:

- TripleCMAS
- LEDS

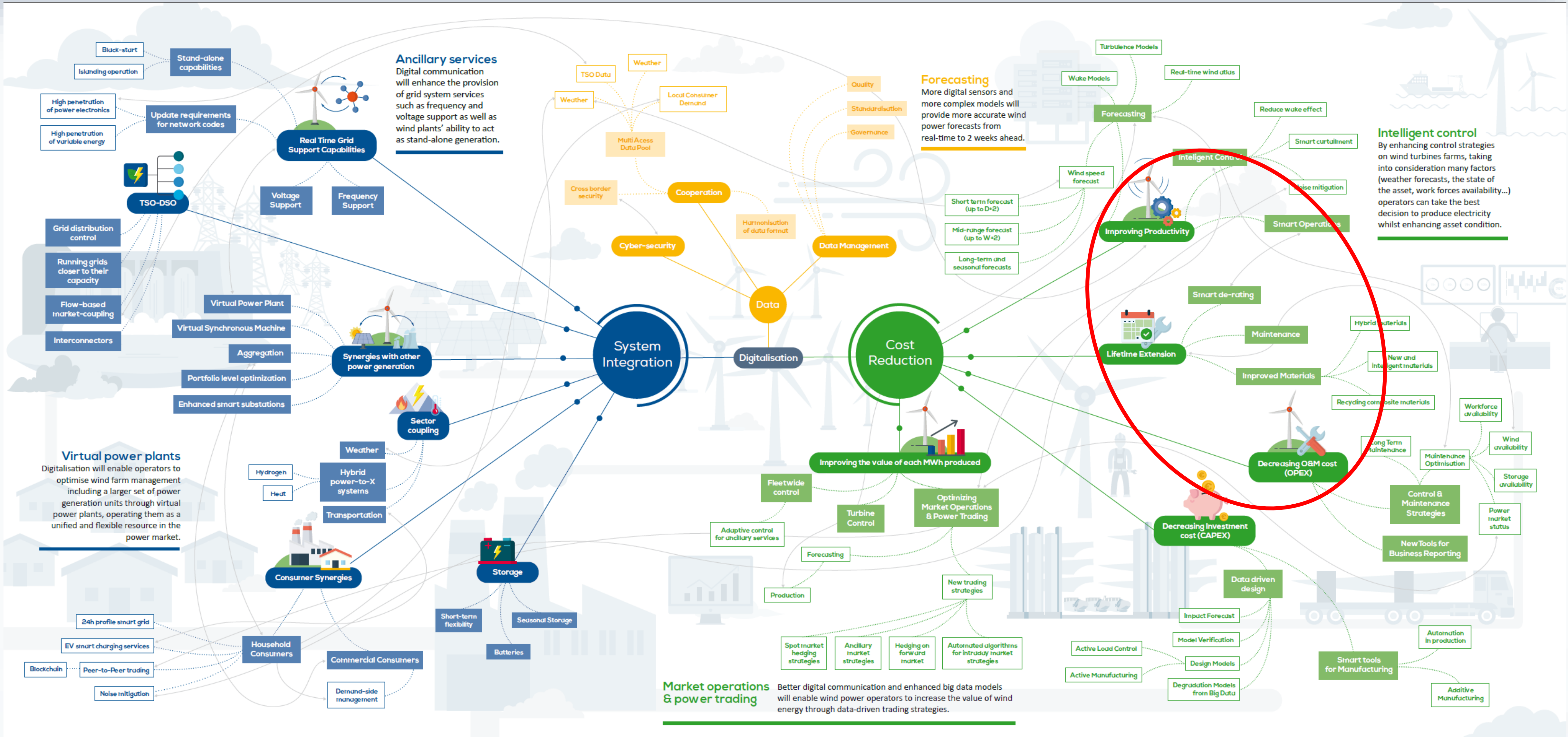
***New DNV GL report** reviews progress, potential and barriers for digitalization in the wind energy industry. Improving operational efficiency (identified by 52% of respondents), decision making (42%) and cost efficiency (40%) are top priorities for further digitalization.*

Balance between sharing data and protecting competitive advantage and Intellectual Property key to realizing full potential of digital technology in the industry.

A new wind is blowing through the energy system – digitalisation.

Over the past decade, most mature heavy industries have experienced a digital revolution, and the wind energy sector is no exception. Enhanced sensor data collection and high quality data exchanges between wind operators and the surrounding energy ecosystem are growing significantly.

WHEN WIND GOES DIGITAL



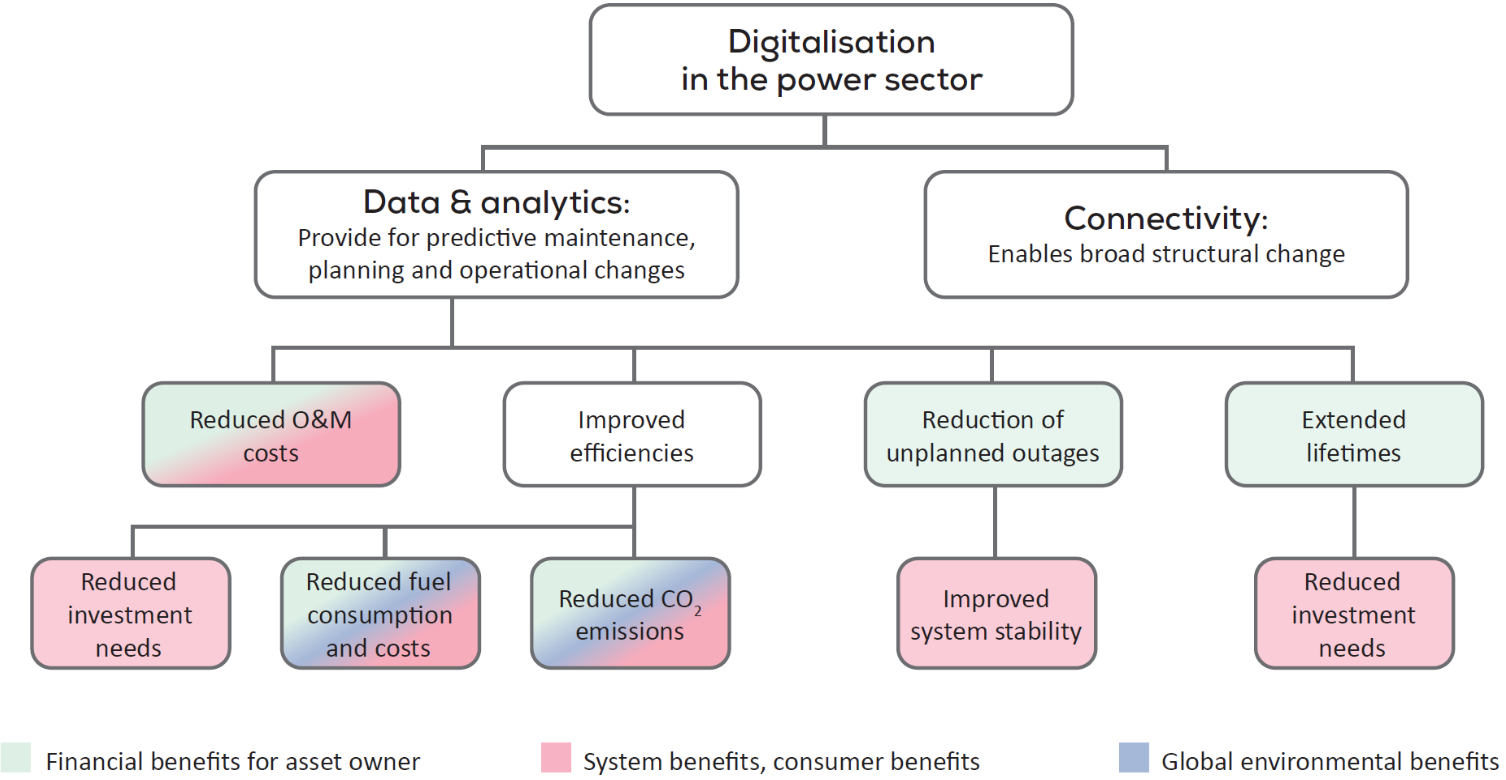
Wind energy digitalisation towards 2030

Cost reduction, better performance, safer operations

WindEurope

FIGURE 1

Potential benefits of digitalisation in the power sector[1].

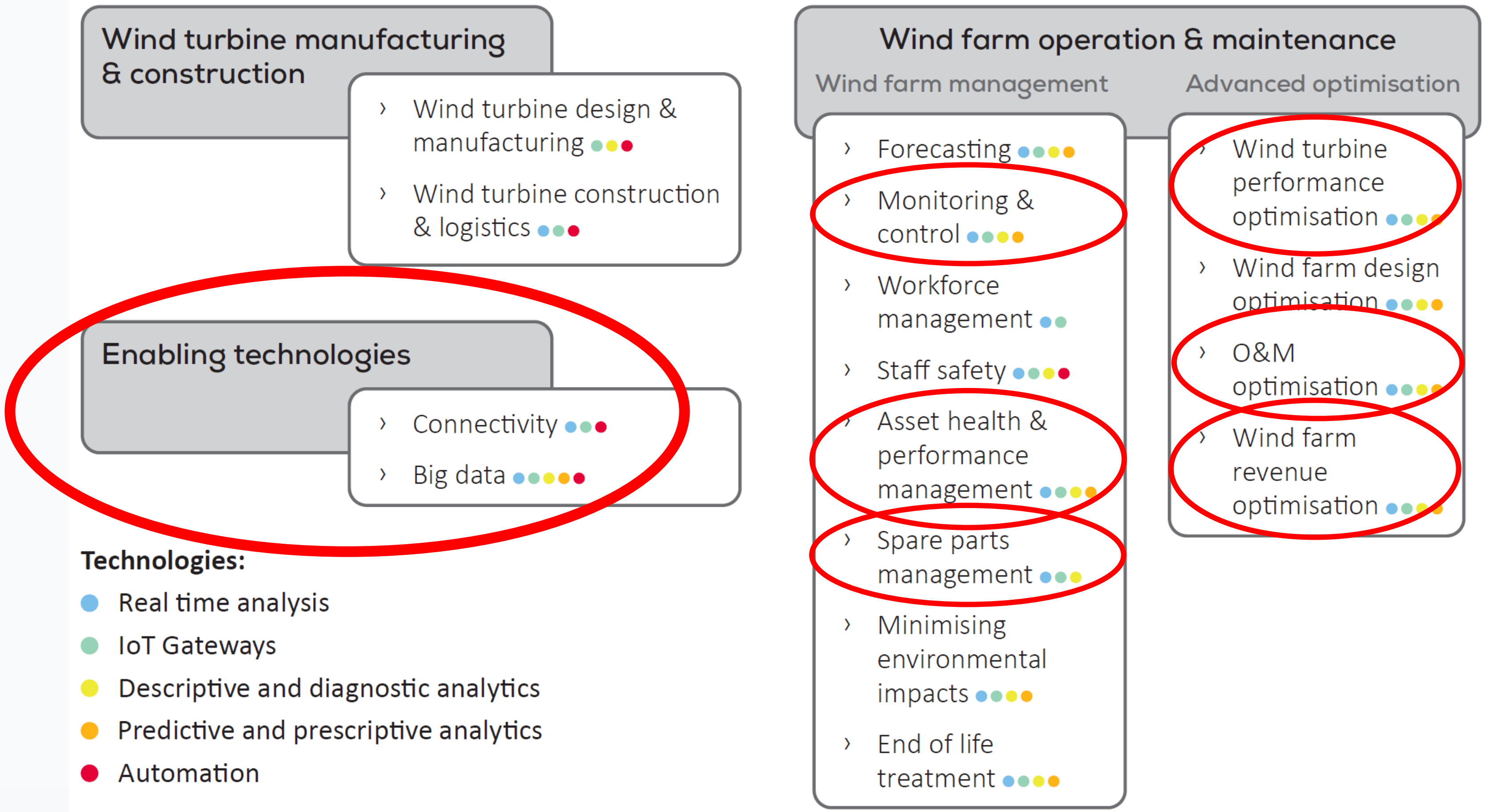


Key message: Digitalisation in the power sector has the potential to bring benefits to the owners of power sector assets, the wider electricity system, consumers and the environment.

Source: International Energy Agency

FIGURE 2

Digital applications and technologies in wind farm O&M, wind turbine manufacturing and construction and enabling technologies



Source: WindEurope

FIGURE 3

Technology categories and tools used today for the digitalisation of wind energy

Technology categories and tools in wind energy digitalisation

Real time analysis
- SCADA
- Aeroelastic simulations
- Climate analysis software
- Cloud analytics
- Robust controllers
- Digital supply chain

IoT Gateways
- Cloud services
- Remote sensing
- Edge computing
- Augmented reality
- Broadband networks(LTE/5G)
- Cellular IoT

Diagnostic and descriptive analytics
- SCADA
- Digital twin
- Root cause analysis
- Condition monitoring
- Computerised maintenance management system (CMMS)
- Building information model

Predictive and prescriptive analytics
- Machine learning
- Artificial intelligence
- Supply chain platforms
- Trading platforms
- Digital twin
- Digital supply chain

Automation
- Autonomous vessels
- Artificial intelligence
- 3D printing
- Digital twin
- Laser/ultrasonic
- Robotics
- Digital supply chain

Source: WindEurope

Big data for wind power forecasting

OPERATOR:
Iberdrola

SOLUTION PROVIDER:
Instituto de ingeniería del conocimiento (IIC)

OBJECTIVE:
Using big data technology to generate prediction models accounting for all meteorological parameters within a radius of tens of kilometres that might influence wind farm power generation

Standard prediction models combine global meteorological models of three-dimensional arrays (e.g. from the European Centre for Medium-Range Weather Forecast or the Global Forecast System) with weather condition data from the reference points of the wind farm and historical performance data to predict potential power output. Big data technology simultaneously uses data from the three-dimensional array models covering an area of several kilometres around the wind farm. This leads to more reliable predictions of the wind farm's power outcome. However, it also calls for greater data storage capacity and post processing of data. This includes filtering variables that influence the prediction of the farm output as well as the operation of the prediction models when accounting for the selected variables.

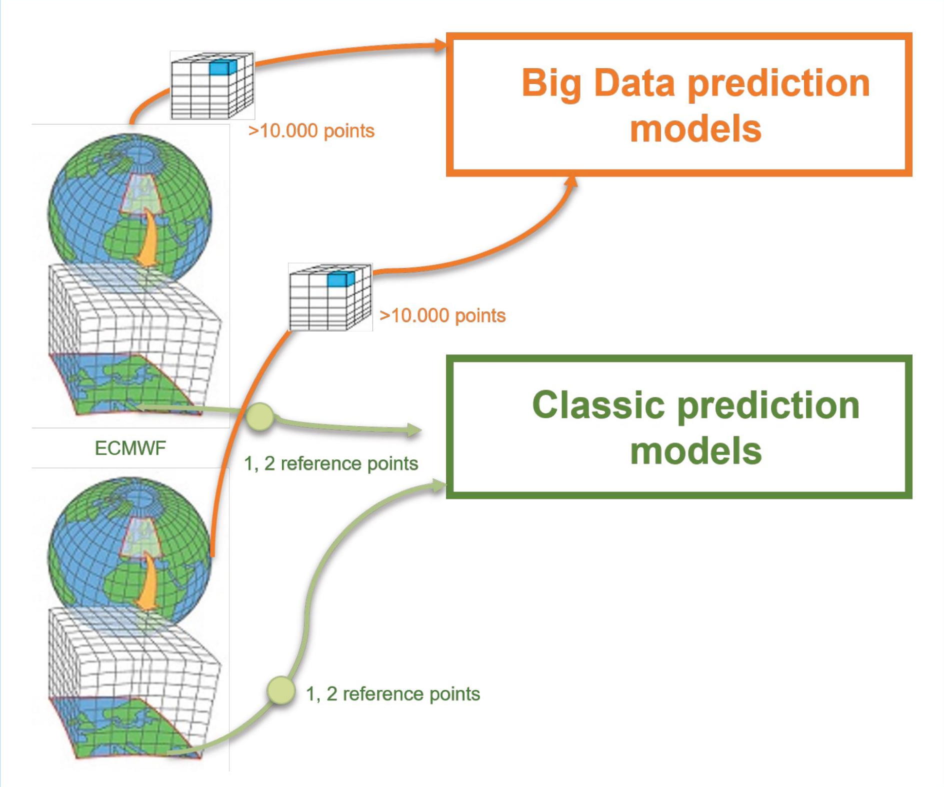
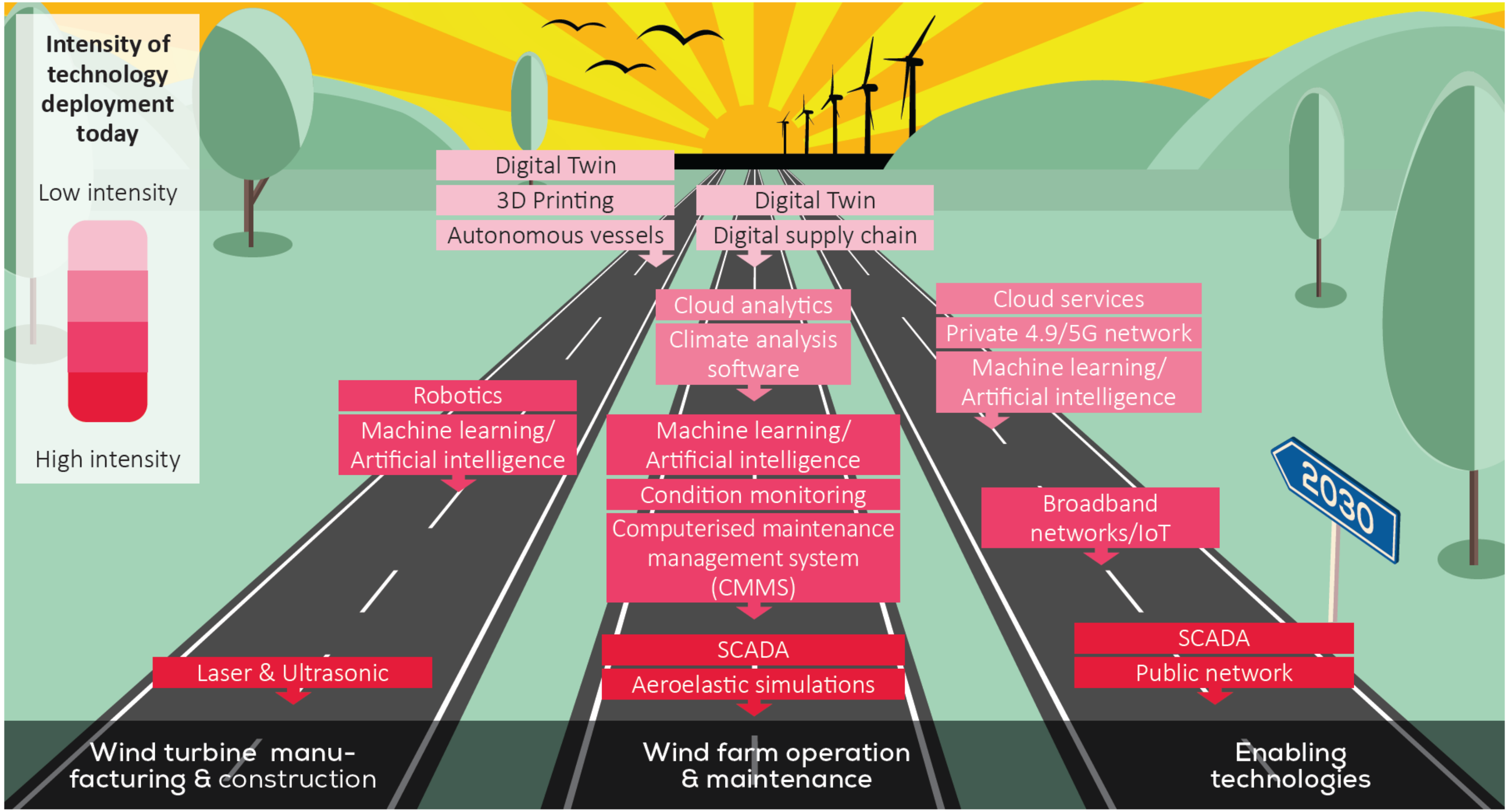


FIGURE 13

Roadmap towards a digital wind sector by 2030 and the application intensity of digital technologies today



Source: WindEurope

ACCESS TO EXISTING DATA - HOW IS THE SITUATION TODAY

Access to existing normalised SCADA data like 10 min average data , 1 min. average data etc. (selected by OEM) enabling further analysis?

Access to existing high frequency WTG raw data for further analysis enabling across fleet monitoring and deeper analysis?

Access to existing WTG parameter data to be able to monitor and compare WTG settings across fleet?

Access to third party WTG data capture systems on major critical WTG components enabling across fleet monitoring and deeper analysis?

THE CHALLENGE AS OFF TODAY:

How do we get access to existing raw data?

How do we get access to raw data in sufficient high quality to take advantage of the new analysis techniques and the global trends in digitalisation?

DNV: *"Balance between sharing data and protecting competitive advantage and Intellectual Property key to realizing full potential of digital technology in the industry."*

However, the report also highlights that the benefits of digitalization could be threatened by issues over sharing data and limited willingness to provide more transparency. Such doubts are particularly felt in the offshore sector where concerns over data sharing (37% of respondents) and inability to access data (25%) were cited as the biggest barriers to further digitalization.

FUTURE TRENDS - HOW TO CREATE VALUE BY COMBINING DIGITAL TECHNOLOGY, PEOPLE AND BUSINESS STRATEGY

Focus is and will continue to be how to increase ROI over asset lifetime.

Third party non invasive high quality data acquisition systems using new modern sensor technologies will have to be retrofitted in existing WTG's and also in new WTG's primarily due to issues with permitted access to existing raw data collected by the OEM.

Data processing and analysis will be performed directly in the WTG's (closer to the data source and online) primarily due to higher sampling frequencies. (Example data collected before at 256Hz → now at 10.000Hz)

New third party monitoring, alarm and failure diagnostics trend analysis systems based on data coming from the new high quality data acquisition systems and using new analysis techniques will be a important driver in increasing ROI over lifetime of wind assets.

FUTURE TRENDS - THE NEW WAY OF MANAGING AND CONDITION MONITORING OF WIND ASSETS FLEETS

Optimization in wind turbine performance and life time:

- Predictive maintenance / failure diagnostics trend analysis enabling anticipation of failures and better planning of service, maintenance and related logistics.
- Life time extension by implementing improved inexpensive monitoring and alarm systems.

Optimization in Operation & Management of wind farms:

- Holistic data approach in logistics and predictive Service & Maintenance strategies for increased availability and reducing power loss in downtime periods.
- New Service & Maintenance concepts considering the wind regime on the actual site, failure predictions and also taking life time extension parameters into account.
- Digital visualisation tools will assist us keeping the overview

We believe

Excellence in operating wind farms is hidden in the data!

SOME EXAMPLE USES OF VENTUS TripleCMAS™ and LEDS™

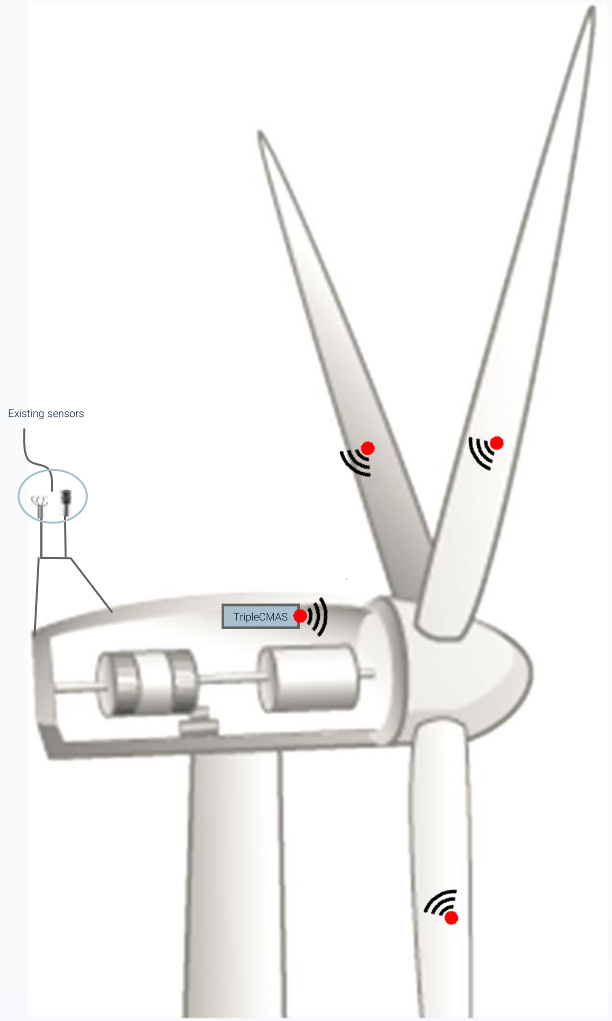
Critical Components Condition Monitoring, fault detection and instant Alarm System

(TripleCMAS™)

Converting the rotor and the entire swept area into a new monitoring instrument Feasible for all existing and future wind turbines

VENTUS TripleCMAS™ ROTOR BLADE SENSOR NODE:

Ventus Patent



Ventus wireless and battery powered sensor node located inside the blade

Ventus RCM wireless and battery powered sensor node located next to iphone5

ALGORITHMS EXAMPLES:

Wind speed

Turbulence Intensity

Wind Direction

Yaw Misalignment

Wake

Icing detection

Heavy Rain and Hail Detection

Relative Blade Pitch Misalignment

Rotor Aerodynamic Imbalance

ALGORITHMS EXAMPLES:

Movement in top of tower

Movements in foundations

Angle between sensors installed in the same blade (Twisting)

Flap wise bending

Edgewise bending

Cumulative estimation of flap wise deflection/displacement/bending over time

Cumulative estimation of edge wise deflection/displacement/bending over time

ALGORITHMS EXAMPLES:

Shocks (peak accelerations) measured inside the blade / Moving objects trapped inside the blades

Punctual shocks in blade structure

Location – where do punctual shocks in blade structure come from?

Outside collisions like Bird Collision

Blade hit by Lightning strike

Orientation of rotor in stopped position

RPM and Rotor Overspeed detection

Monitoring cut-in, cut-out and re-cut-in

Speed and behaviour of Blade pitch angle changes

ALGORITHMS EXAMPLES:

"Wind farm Maximiser" WTG's collaborating to minimize wake in entire wind farm

Humidity inside blade

Temperature inside blade

TripleCMAS: Accelerometers inside blades, nacelle and tower

Calibration of sensors on installation

Overtime monitoring of **relative angles between blades:**

- Angle between A & B
- Angle between A & C
- Angle between B & C

In this example, two main blade provocations were performed.

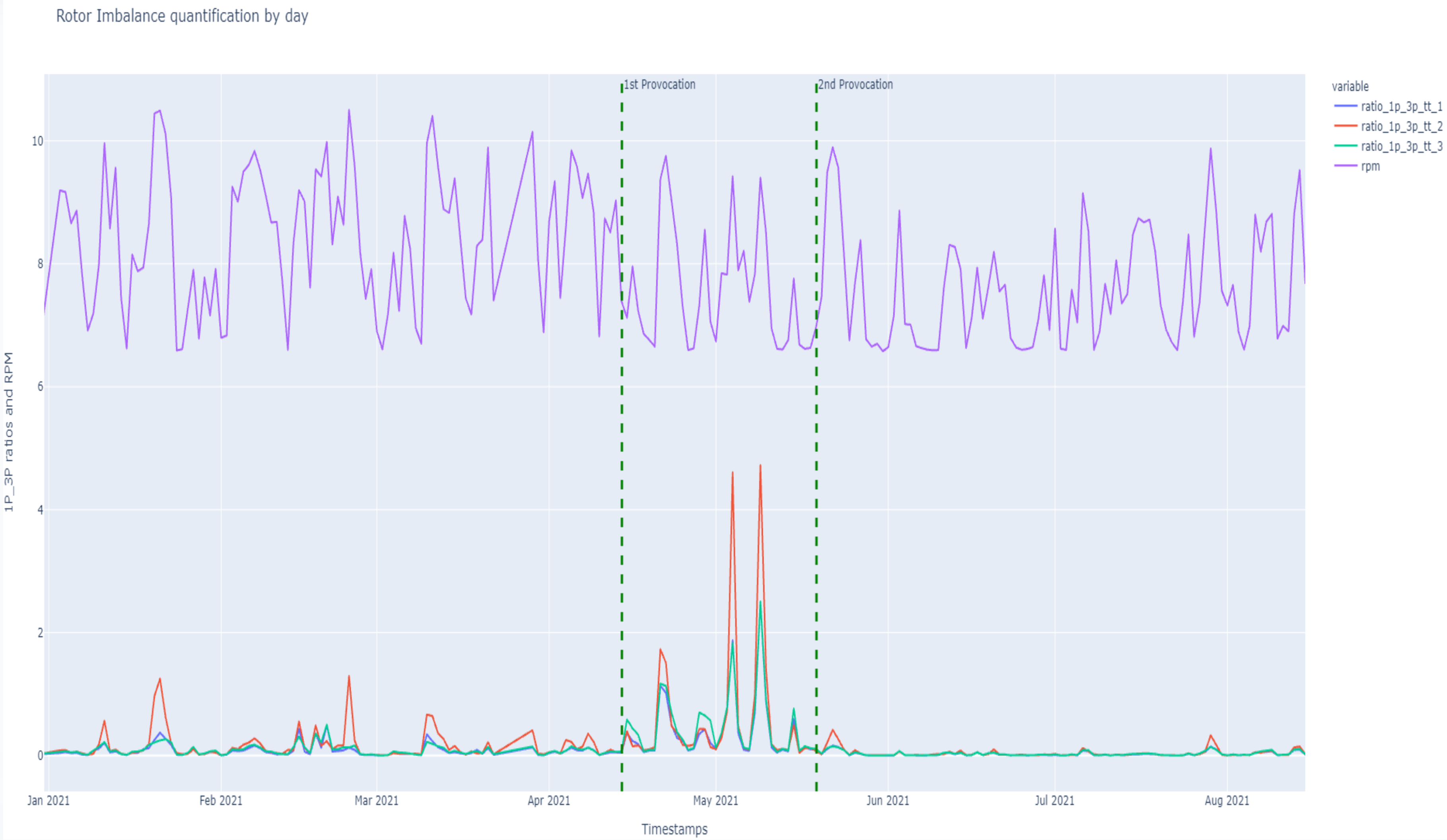
1. One blade angle was changed (impacting two relative calculations)
2. The blade was put back to its initial value

WTG#3 8MW – TRIPLECMAS: OVERTIME ROTOR IMBALANCE EVALUATION

We are using the 1P & 3P frequencies of the data in our nacelle sensors to evaluate (with a ratio) the rotor imbalance:

- ⇨ Ratio of Channel 1 of sensor
- ⇨ Ratio of Channel 2 of sensor
- ⇨ Ratio of Channel 3 of sensor
- ⇨ RPM

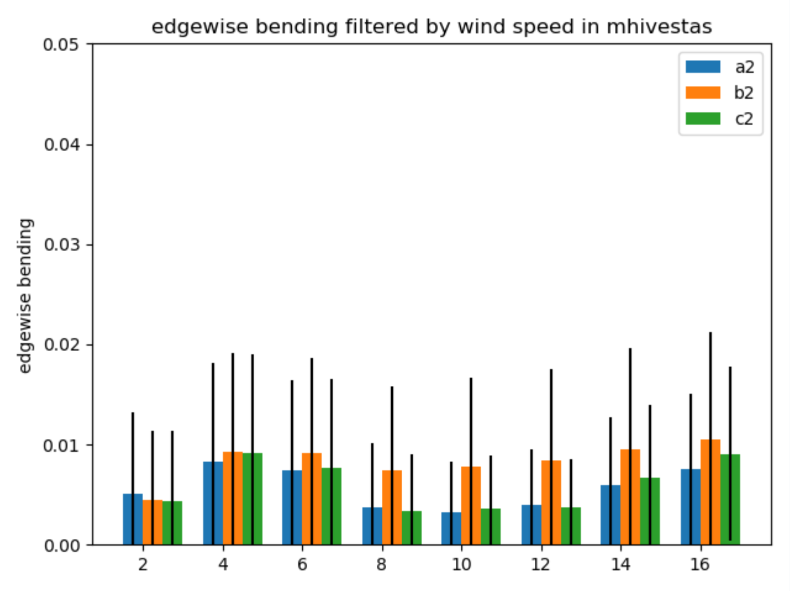
- Before 2021-04-14: testing for the upcoming provocation were on-going.
- During the provocation: **high values of imbalance** (The higher the RPM the higher the imbalance).
- After 2021-05-19: Our data suggests that the imbalance level is back to what it was before.

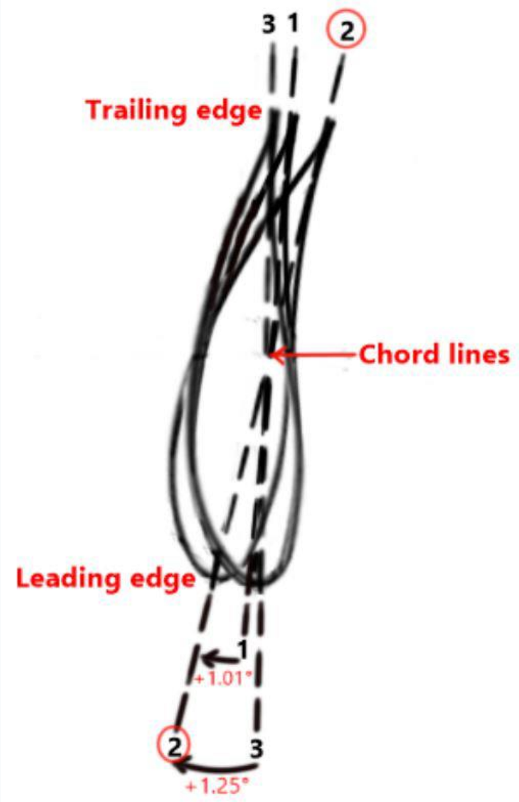


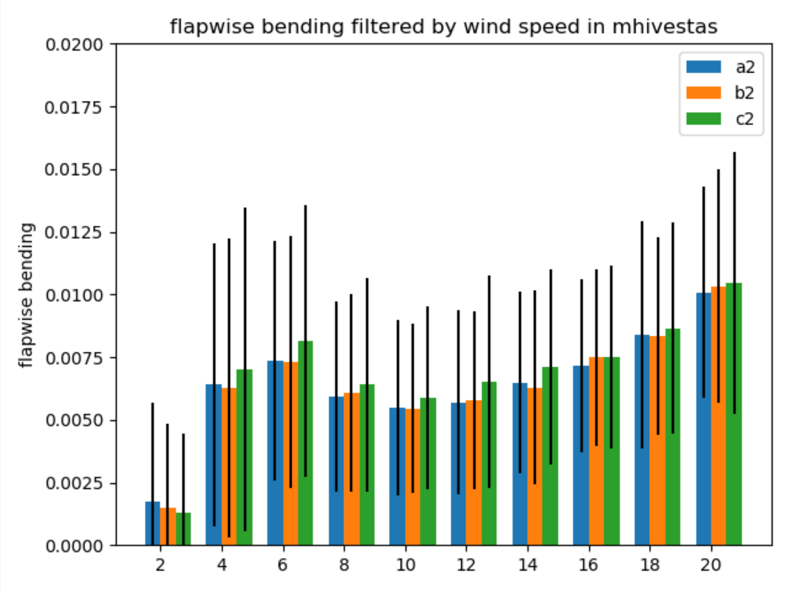
TripleCMAS – FLAPWISE AND EDGEWISE BENDING VERIFICATION EXAMPLES TripleCMAS SENSOR NODES LOCATED 25M OUT IN BLADES: 8MW - WTG #3:

Ventus Patent

- ✓ Measurement of the relative difference in blade aerodynamic efficiency decide the re-pitching strategy



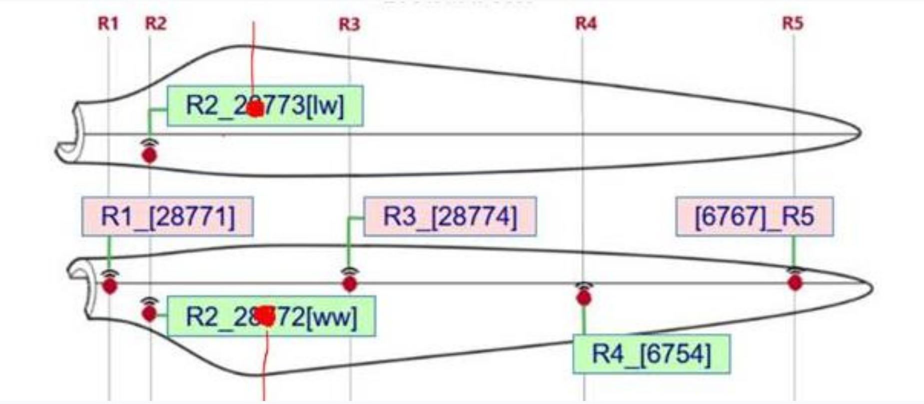


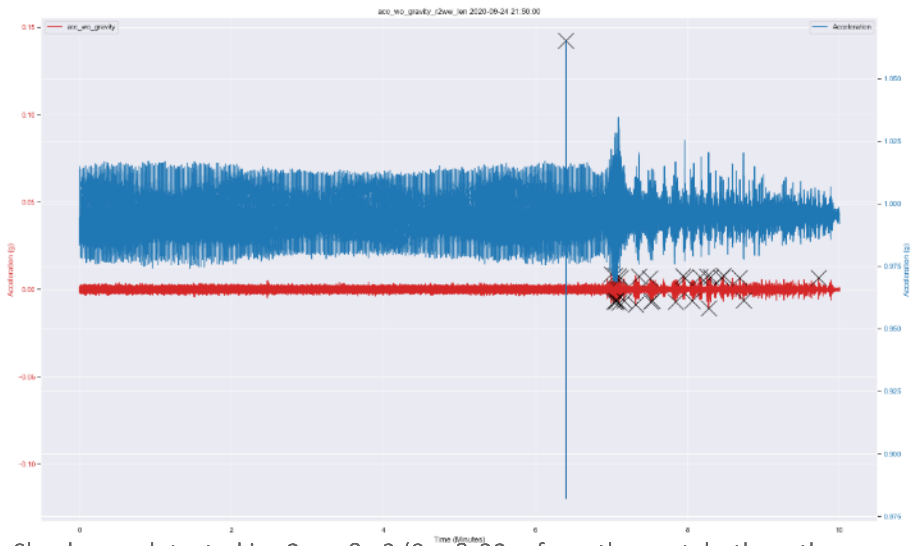


Recommended actions for the correction of the detected relative blade pitch misalignment: Pitch angle should be adjusted to the most efficient pitch angel, which is blade b2

TripleCMAS™ DEMONSTRATED THE ABILITY TO "SEE" CRACKS IN THE BLADES

Ventus Patent





Shocks are detected in r2ww & r3 (9m & 32m from the root, both on the same side of the blade). To be noticed the large peak, in terms of acceleration.

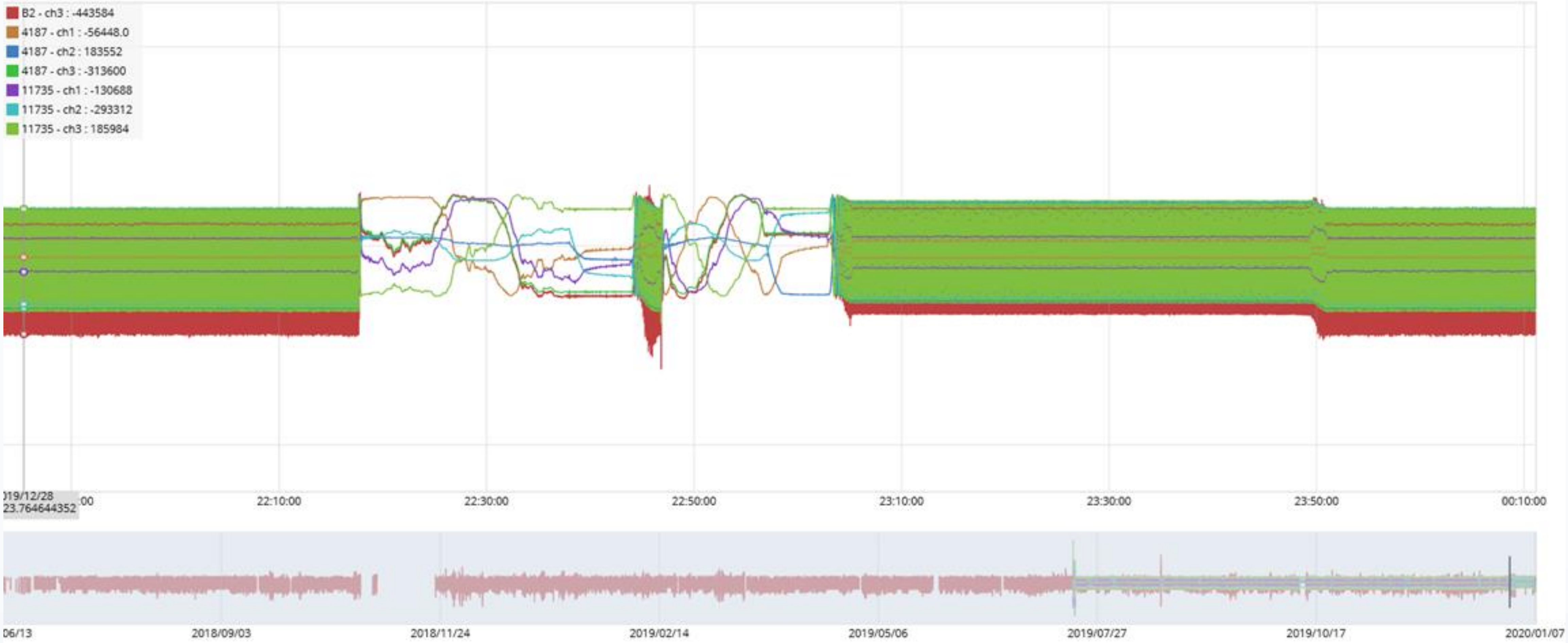
TripleCMAS sensor nodes on 2 blads located in test rig. See red dots.

In beginning of the testing test centre registered by listening 4 times "crack sounds"

In same time period TripleCMAS detected 14 shocks in location in between R2 and R3 (closet to R2).

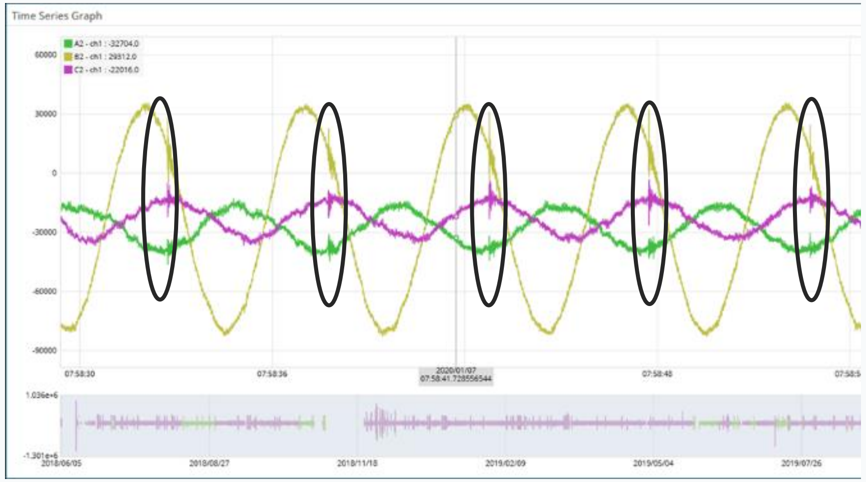
Ventus Patent

Bolt broken in Pitch Cylinder

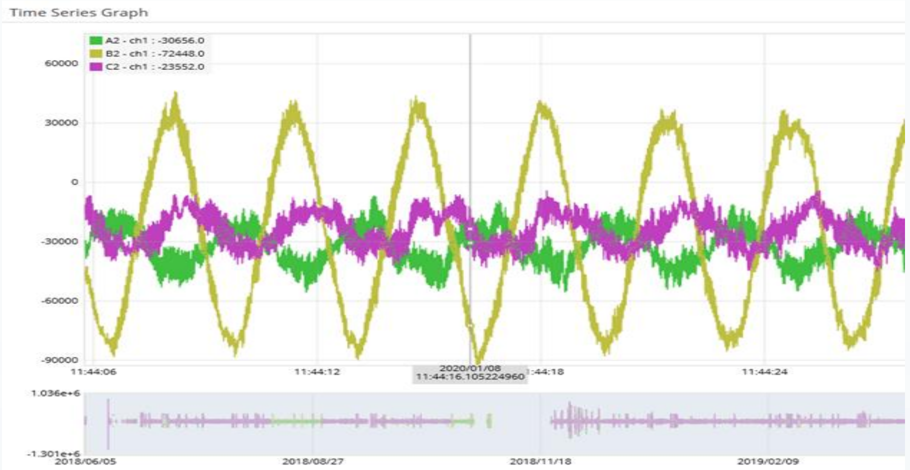


Ventus Patent

Pitch hydraulics cylinder repair not OK – new knocking/vibration occur after repair →

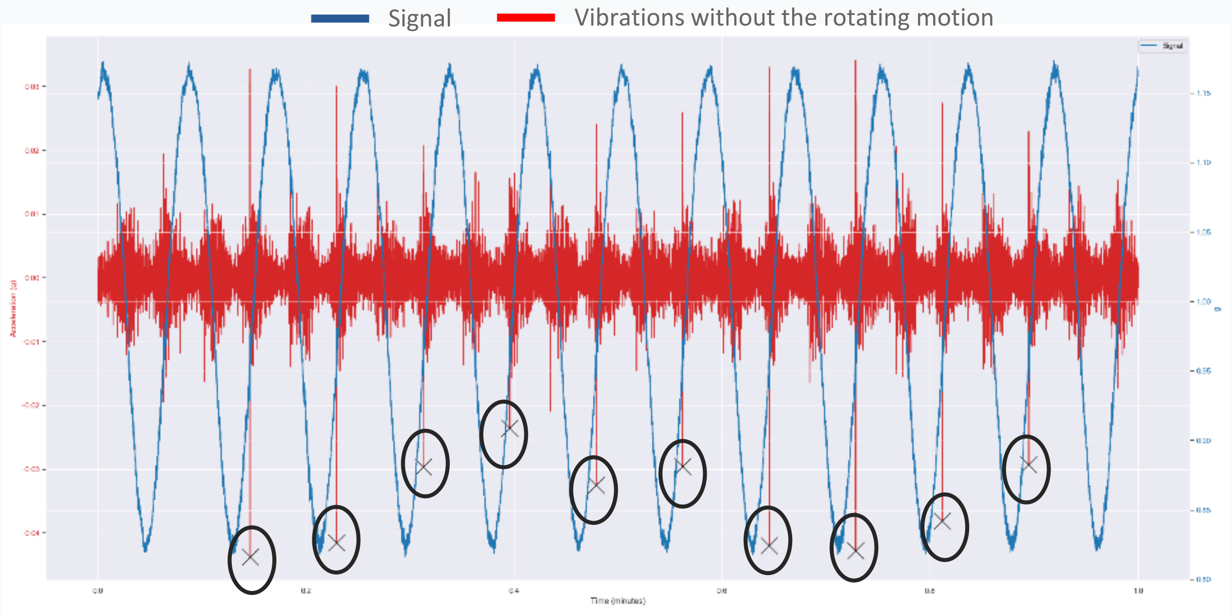


After second repair, now knocking disappeared →

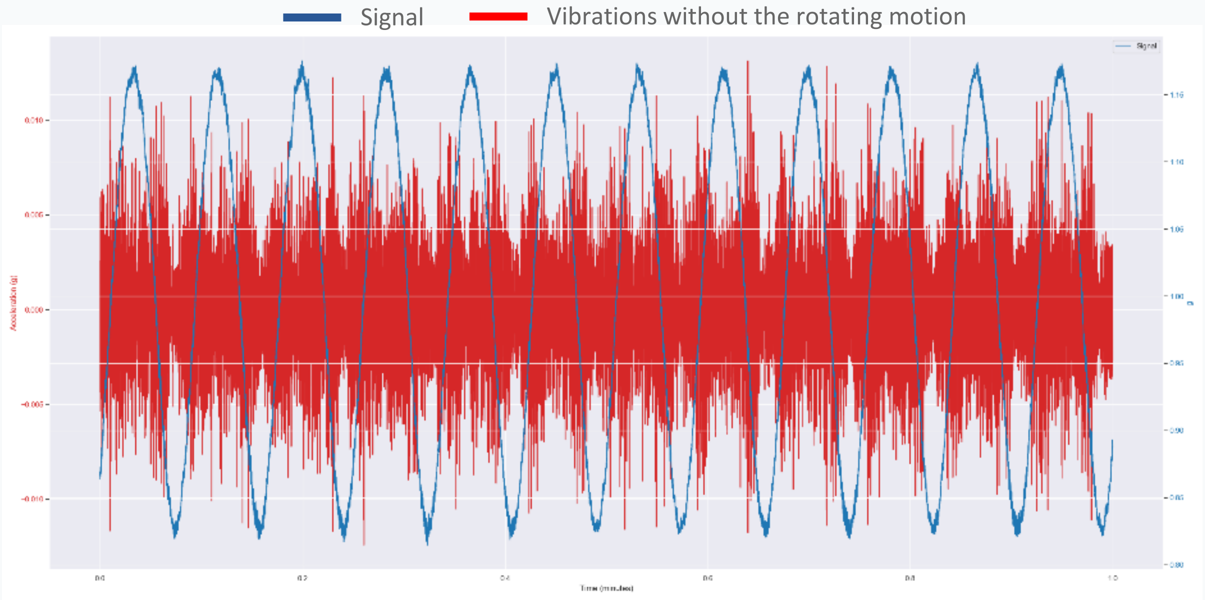


Ventus Patent

Detection of objects moving inside the blade



Blade B – objects inside blade

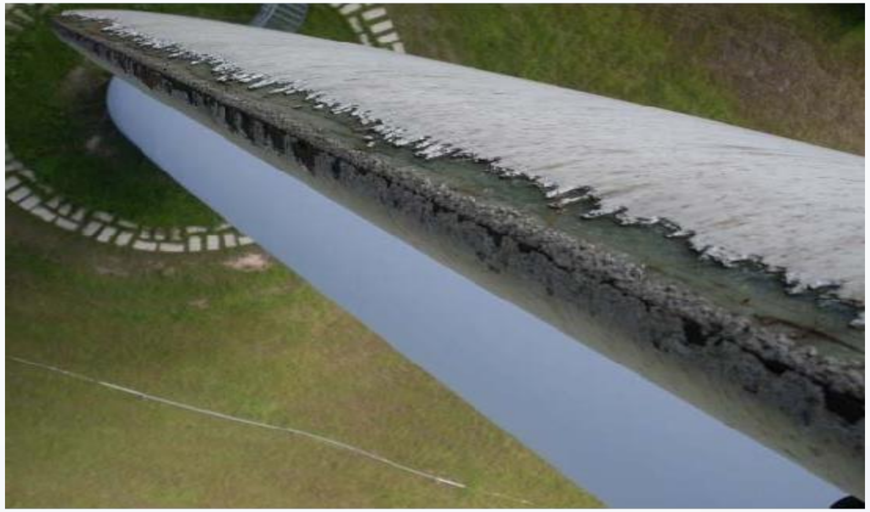


Blade A – no objects inside blade

Detection of objects moving inside the blade

With TripleCMAS™ you will be able to monitor heavy rain and hail = Leading Edge Erosion can be avoided with TripleCMAS™ by introducing a "safe mode in operation" reducing the tip speed during defined extreme precipitation events.

Texas hailstorm $70-80 million loss in 2019 (reported by Insurance Insider on 16/01/2020 could have been avoided if TripleCMAS™ was installed in the affected windfarms



Now		Tomorrow
256Hz	→	10.000Hz

Ventus Patent filed

LEDS™

Monitoring
Lighting and **E**lectrostatic **D**ischarge
System

Ventus Patent filed

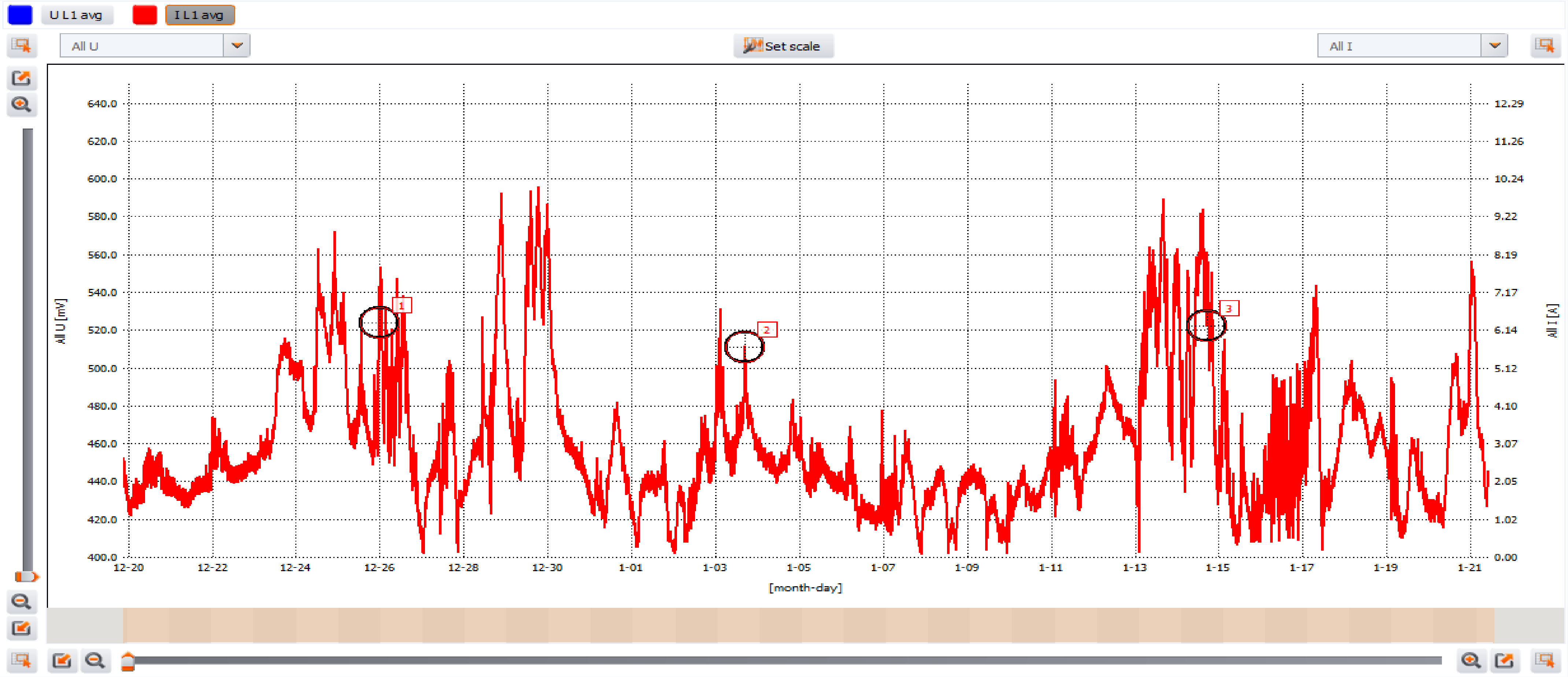
Static imbalance discharge Gamesa 2MW WTG at still stand

The pertinent questions that inspired the Ventus LEDS™

- How can static imbalance be used for powering Ventus TripleCMAS sensor node?
- If yes, can we by this further extend the capabilities of the TripleCMAS system?

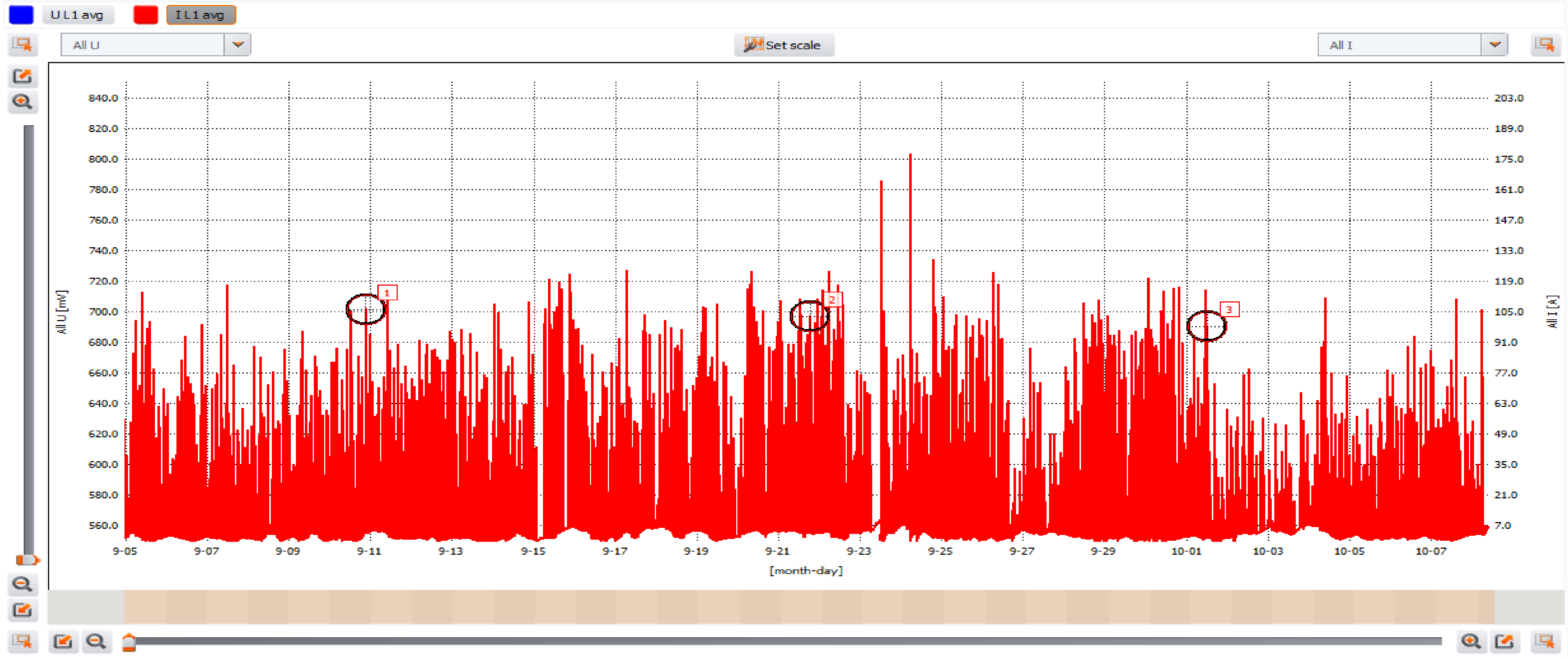
MONITORING ELECTROSTATIC DISCHARGE EXAMPLE (OK GROUNDING SYSTEM)
E82, MONITORED OVER 1-MONTH PERIOD

Ventus Patent filed



MONITORING ELECTROSTATIC DISCHARGE EXAMPLE (DEFECT GROUNDING SYSTEM) NM72, MONITORED OVER 1-MONTH PERIOD

Ventus Patent filed

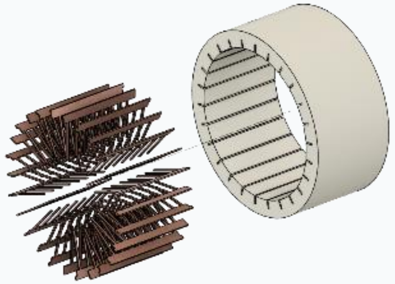


LEDS™ SYSTEM – PROTOTYPE DEVELOPMENT

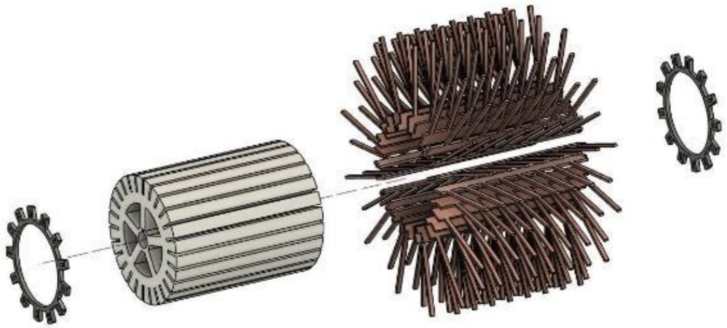
Ventus Patent filed

Ventus electrical machine design, manufacture and assembly for Prototype B

Stator

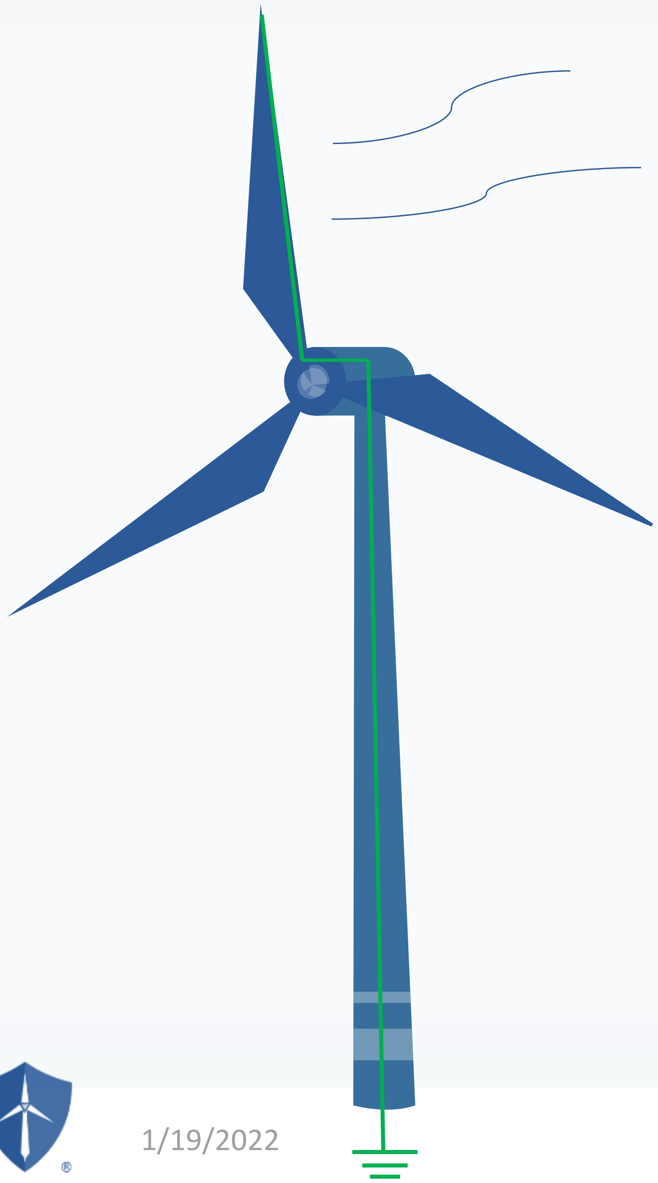


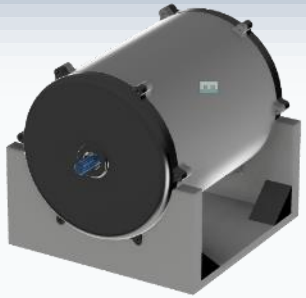
Rotor

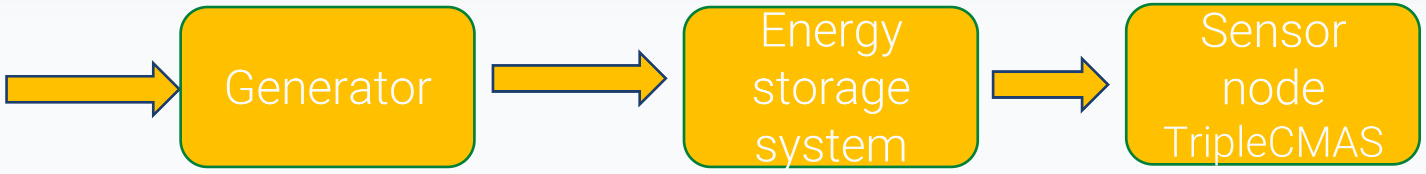


3D printed parts

Ventus Patent filed







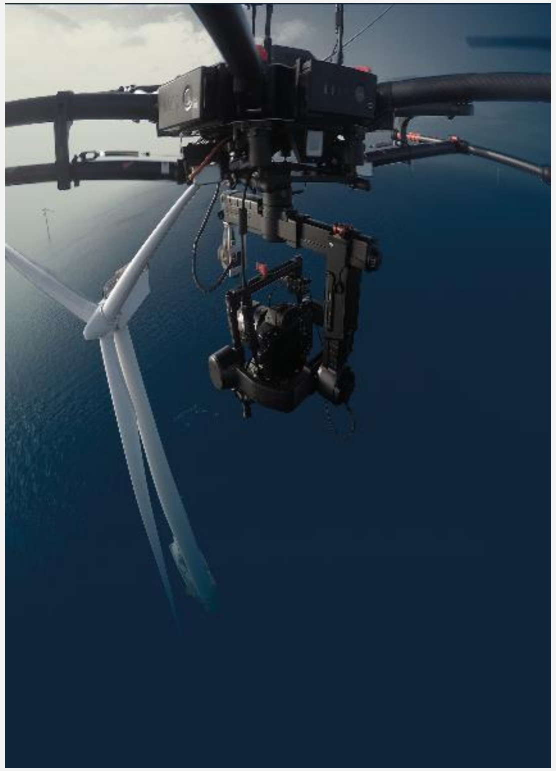
- ✓ LEDS is the hybrid energy power harvester providing power for the TripleCMAS wireless sensor nodes.
- ✓ LEDS is also a novel monitoring system which can be retrofitted to WTG's (and all structures with a lightning grounding system).
  - Monitoring the quality and efficiency of the lightning grounding system
  - Monitoring lightning strike
  - Monitoring roughness of blade surface
  - Monitoring wind speed
- ✓ Comparison of measurements from blades in the same WTG will be useful, but also comparison with reference value or values from other wind turbines in the wind farm
- ✓ LEDS provide alarm if anything unusual happens like reduced efficiency of the grounding system and if it detect lightning strikes hitting the individual blade

Ventus Patent

With traditional periodic inspection of the lightning system you only see the actual status of the lightning protection system.

With TripleCMAS™ you will be able to permanently monitor the efficiency of Lightning & Electrostatic Discharge System (Ventus LEDS™) grounding and correct by-passage of pitch bearings and main shaft bearing
= Significant reduction in damages due to lightning and consequential damages

THANK YOU FOR YOUR ATTENTION!



Austria (HQ)

Ventus Engineering GmbH

Simmeringer Hauptstraße 101/1-6/327,
1110 Vienna,
Austria
+ 43 1 535 00 44 200

Austria (R&D)

Ventus Wind Services GmbH

Simmeringer Hauptstraße 101/1-6/327,
1110 Vienna,
Austria
+ 43 1 535 00 44 200

Denmark

Ventus Wind Services A/S

Lyshøj Møllevej 2
8970 Havndal,
Denmark
+ 45 20 88 52 52

Scotland

Ventus Wind Services UK Ltd.

1 Finlaysan Lane, Kaumend, Carnwatch
South Landarkshire, ML11 8TA,
United Kindom
+ 44 771 733 0970

sales@ventus.group I +43 1 535 00 44 200 I www.ventus.group