

Potential solution for rain erosion of wind turbine blades

Hasager, Charlotte Bay; Bech, Jakob Ilsted; Kusano, Yukihiro; Sjöholm, Mikael; Mikkelsen, Torben Krogh; Bak, Christian; Skrzypinski, Witold Robert; Vejen, Flemming; Madsen, Martin Bonde; Bayar, Mertcan; Saldern, Morten ; Halling, Kaj M.

Publication date:
2017

Document Version
Publisher's PDF, also known as Version of record

[Link back to DTU Orbit](#)

Citation (APA):
Hasager, C. B., Bech, J. I., Kusano, Y., Sjöholm, M., Mikkelsen, T. K., Bak, C., ... Halling, K. M. (2017). Potential solution for rain erosion of wind turbine blades [Sound/Visual production (digital)]. Wind Energy Denmark 2017, Lyngby, Denmark, 02/10/2017

DTU Library

Technical Information Center of Denmark

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Potential solution for rain erosion of wind turbine blades

*Charlotte Hasager, Jakob Ilsted Bech, Yukihiro Kusano, Mikael Sjöholm, Torben Mikkelsen, Christian Bak, Witold Skrzypinski (DTU)
Flemming Vejen (DMI)
Martin Bonde Madsen (R&D)
Mertcan Bayar (E.ON)
Morten Saldern (Vattenfall)
Kaj M. Halling (Vestas)*

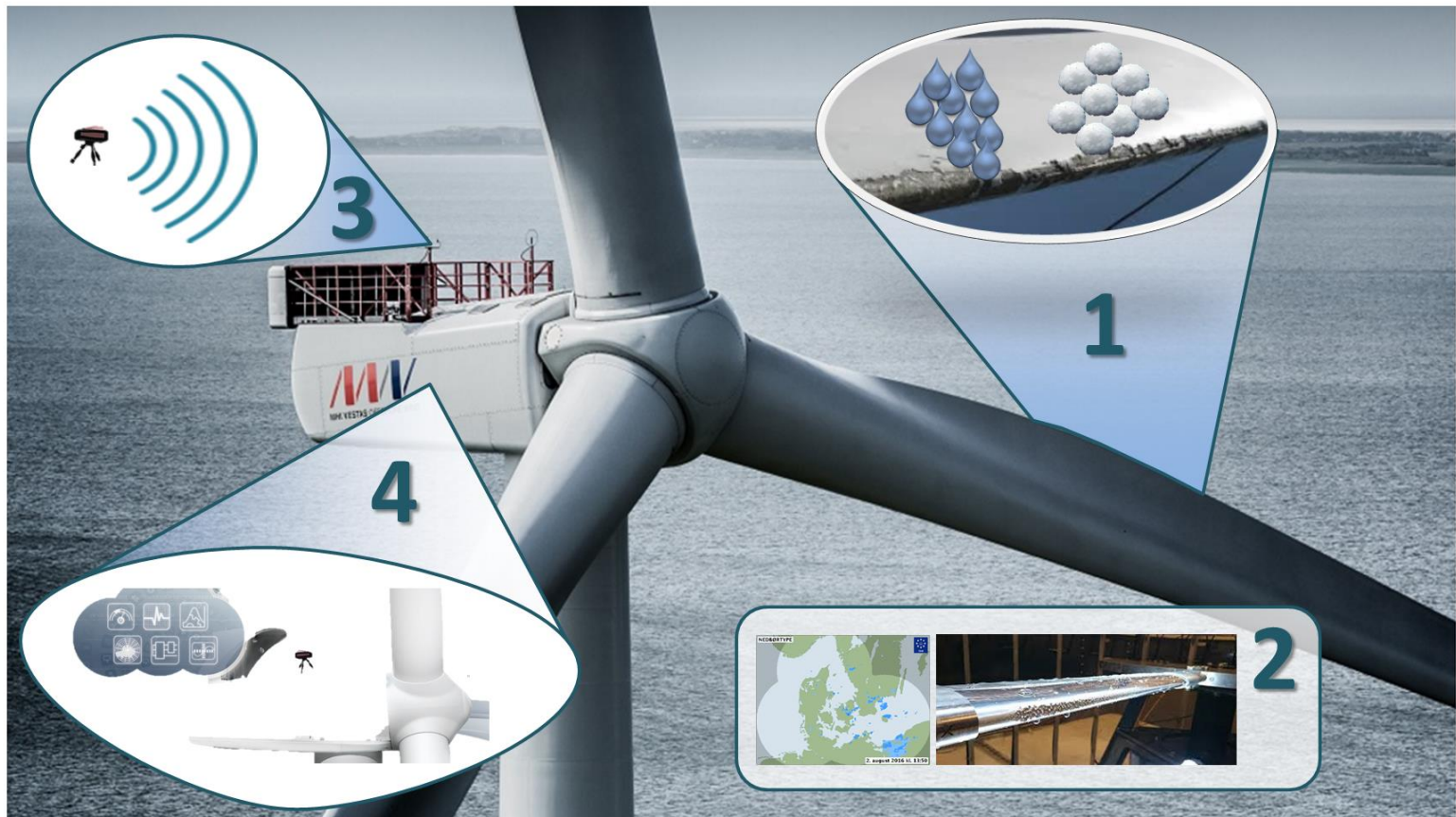
WIND
ENERGY
DENMARK

EROSION

Wind turbine blade erosion:
Reducing the largest uncertainties

Content

- Hypothesis
- Rain data from disdrometer, lidar and radars
- Rain erosion testing, analysis and modelling
- Control of turbine based on rain input
- The business case
- Next steps



1. **Research hypothesis:** Erosion damage is mainly generated during heavy precipitation (big drops of rain or hail), which occurs in a very little fraction of the turbines operation time. By reducing the tip speed of the blades in these few hours a significant extension of the leading edge lifetime can be obtained with negligible loss of production.
2. **Methodology:** Define rain and hail erosion classes to quantify leading edge blade in-field and in lab testing. Correlations between rain intensity, droplet size, impact speed, materials properties, etc. will be established.
3. **Measurement Device:** Low-cost prototype for precipitation measurement on site and real time warning device enabling modern control of wind turbines.
4. **Erosion safe mode:** A safe mode control based on the erosion classes to control the wind turbine, reducing the tip speed under severe conditions – preventing aerodynamic degradation and reducing maintenance costs.

Disdrometer

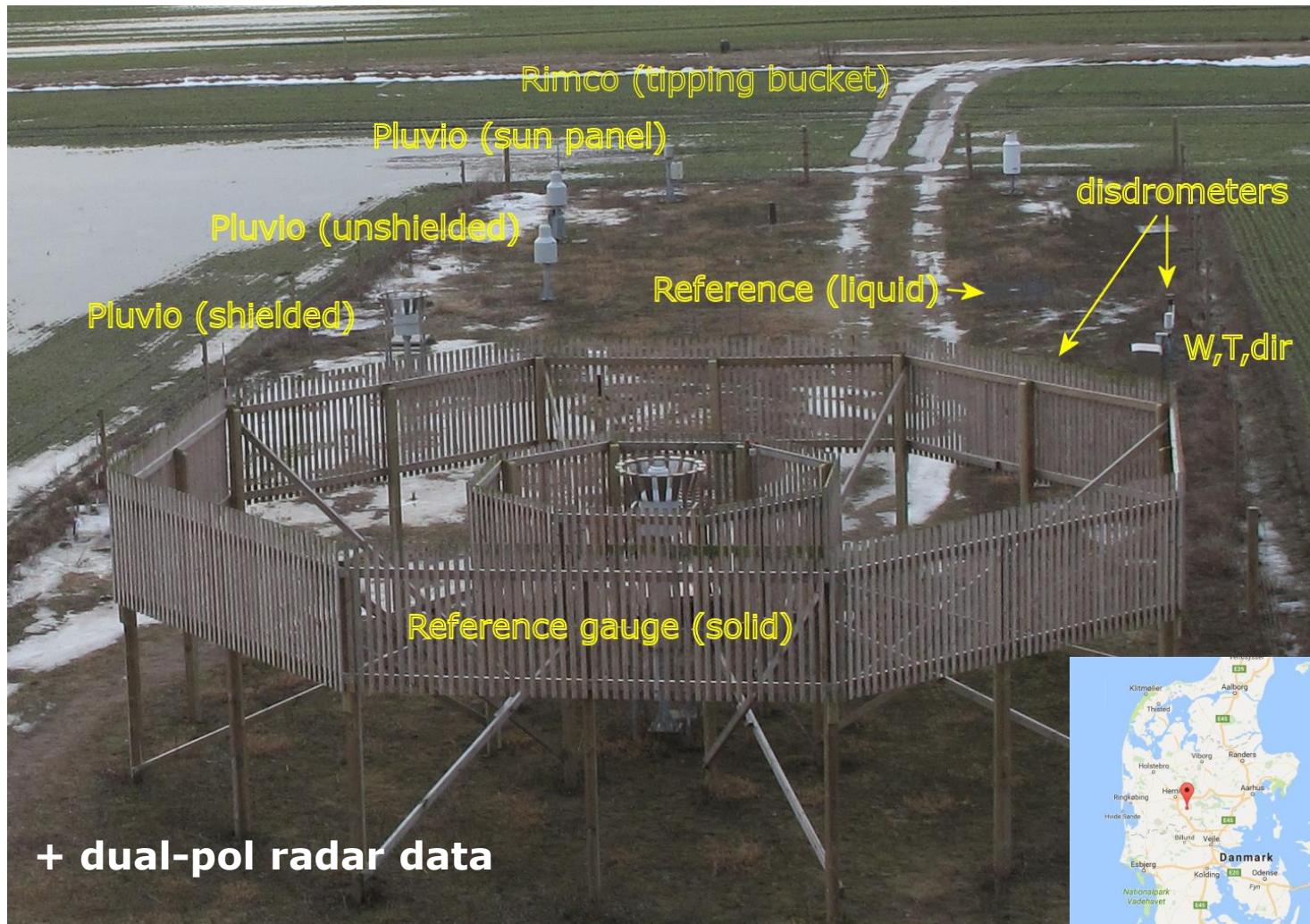


The OTT Parsivel² is a laser disdrometer for all precipitation types.

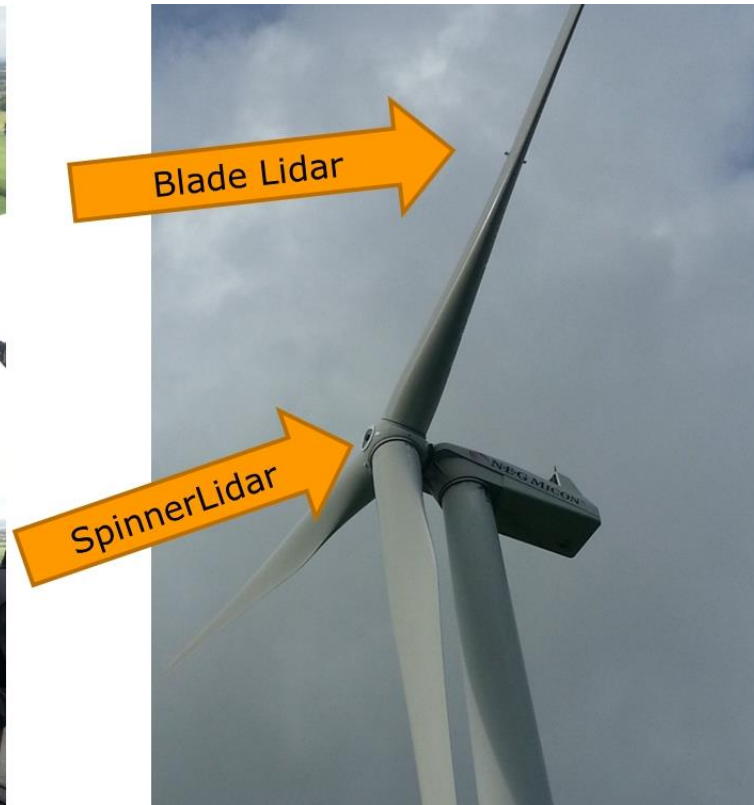
It captures both the size and speed of falling particles, classifying them into one of 32 separate size and velocity classes.

The raw data are used to calculate the type, amount, intensity and kinetic energy of the precipitation, the visibility in the precipitation, and the equivalent radar reflectivity.

Validation of instruments and various experiments at DMI station
Data record available from Voulund test field (HOBE) 2012-now



Lidars at wind turbines



Turbine-mounted SpinnerLidar and blade-mounted Lidars developed in a previous DTU-lead project. The novel precipitation detection lidars are utilizing existing hardware but with novel processing algorithms.

Precipitation from lidar

A remote sensing Doppler lidar (LIght Detection And Ranging) instrument is similar to a radar but operates with laser light, although invisible for the naked eye at a wavelength of about $1.5\mu\text{m}$ in the more eye-safe range of the near-infrared spectral region

For standard lidar-based wind measurements, it is only the location of the Doppler spectrum along the frequency/velocity axis that is of interest. The shape of the spectrum is not utilized for wind measurements and multiple peaks from both the aerosols moving with the wind and falling water drops are merely a cause for outliers in the estimated wind speed time series that requires filtering.

However, the proposed precipitation lidar will utilize the extra Doppler spectral intensity information that hitherto has not been used.

WindScanner lidar for precipitation



The test site at DTU Risø Campus with three WindScanners to be measuring in the vicinity of the Parsivel disdrometer.

Lufft WS100-UMB – Radar Precipitation Sensor



Absolutely maintenance-free and extremely fast measurement of precipitation type (Rain, snow, sleet, freezing rain, hail) and intensity, thanks to radar measurement technology.

Radar reflection method to measure velocity on hydrometeors by 24-GHz-Doppler radar.

Correlation and determination of drop size classes to provide DSD matrix in 11 classes.

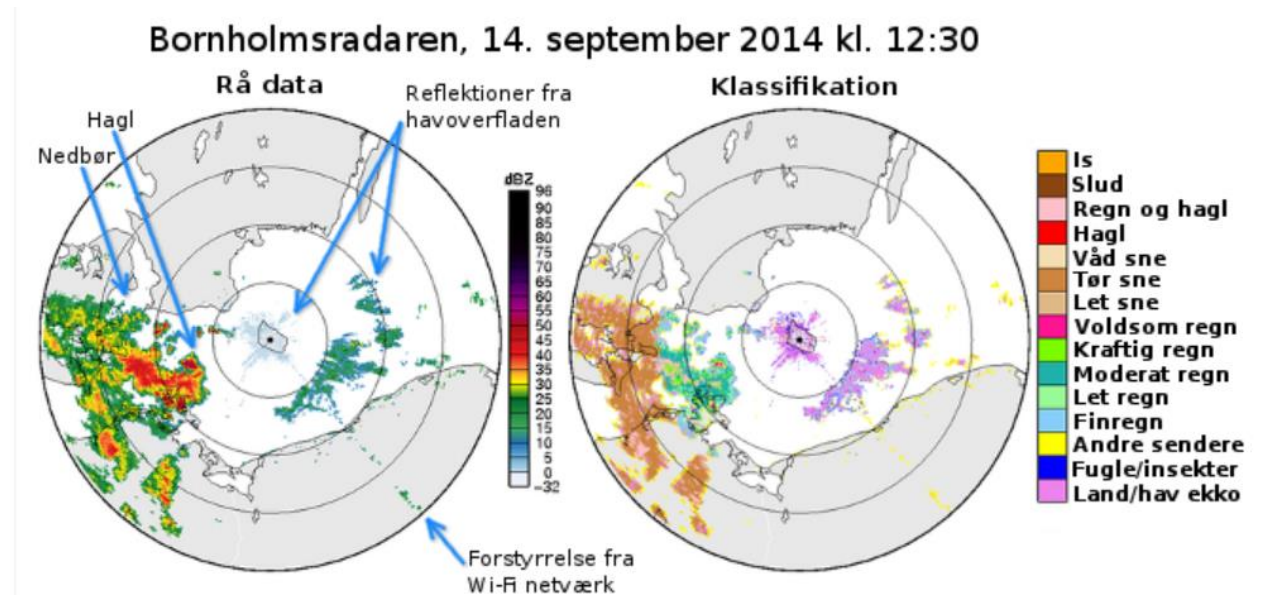


<https://www.lufft.com/products/precipitation-sensors-287/ws100-radar-precipitation-sensor-smart-disdrometer-2361/>

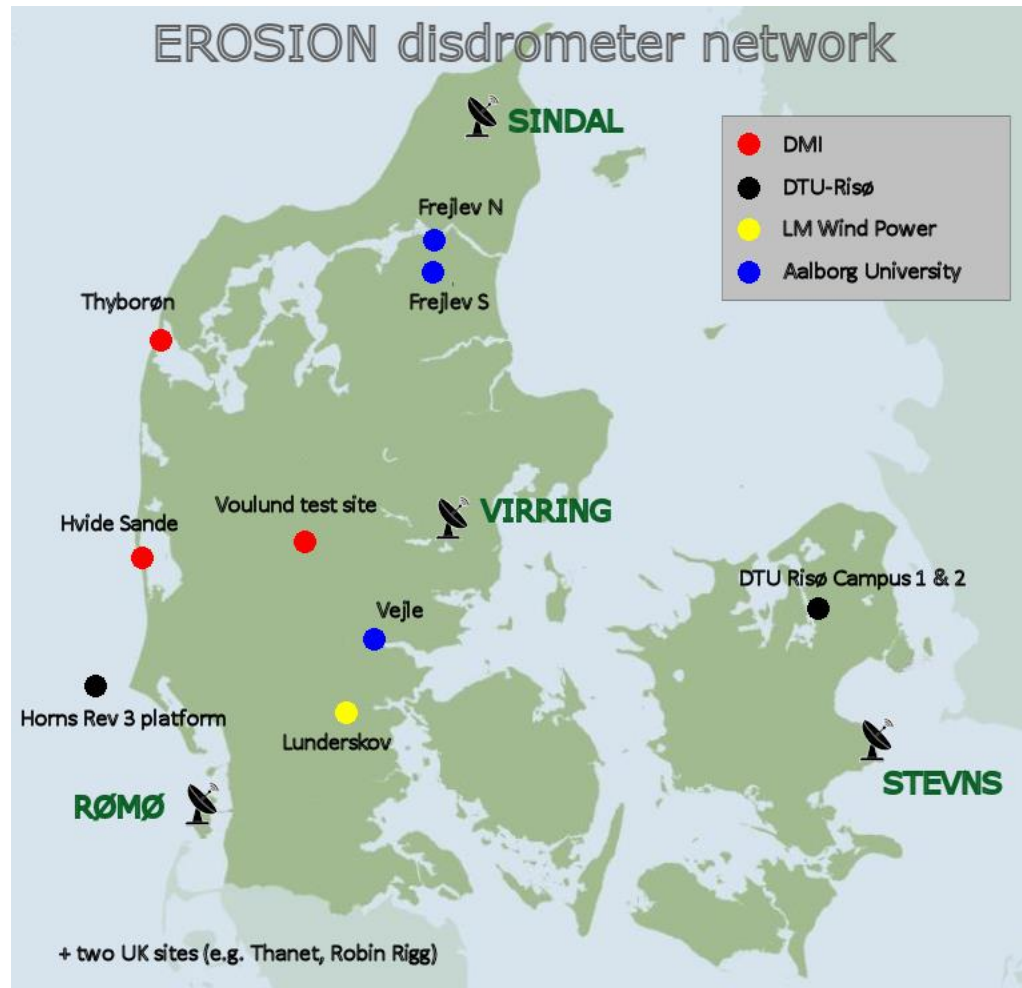
Radar dual-polarization



DMI radar at Stevns.



EROSION disdrometer network and DMI radars



Rain erosion testing

History of Rain Erosion Testing

- Rain Erosion phenomenon originally investigated in aviation industry on primarily fixed wing aircrafts
- Early efforts led to development of both main concepts and standard

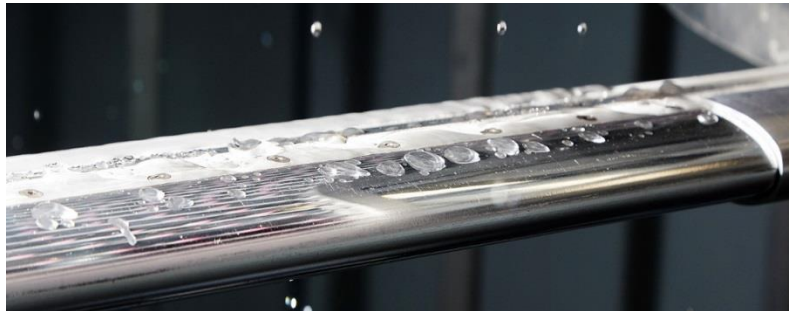
Main Concepts of Rain Erosion Testing

- Whirling Arm principle
- Water Jet principle

Standardization within Rain Erosion Testing

- ASTM G73 standard was first effort to standardize Rain Erosion Testing within aviation
- Development of new standards is currently ongoing, with focus on Wind Turbine Blades
- Standardization work being led by both ISO and DNV-GL

Rain erosion testing

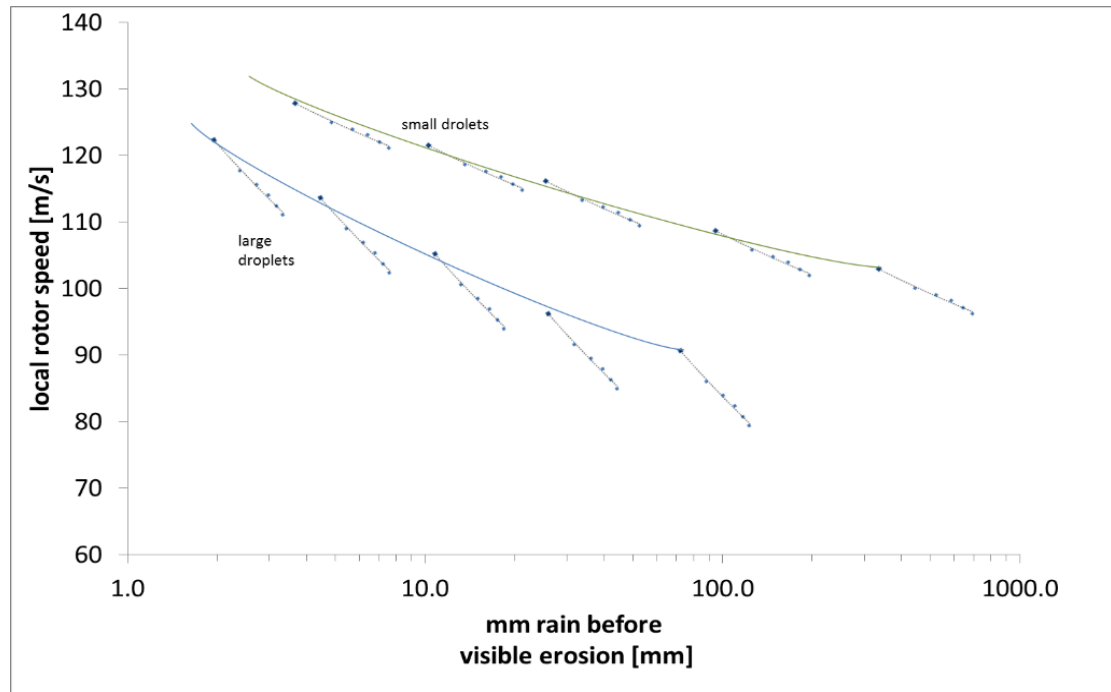


Rain Erosion Tester by R&D Test systems



Example of specimen

Rain erosion testing: schematic representation



Schematic representation of mm rain to cause erosion for two different droplet sizes.

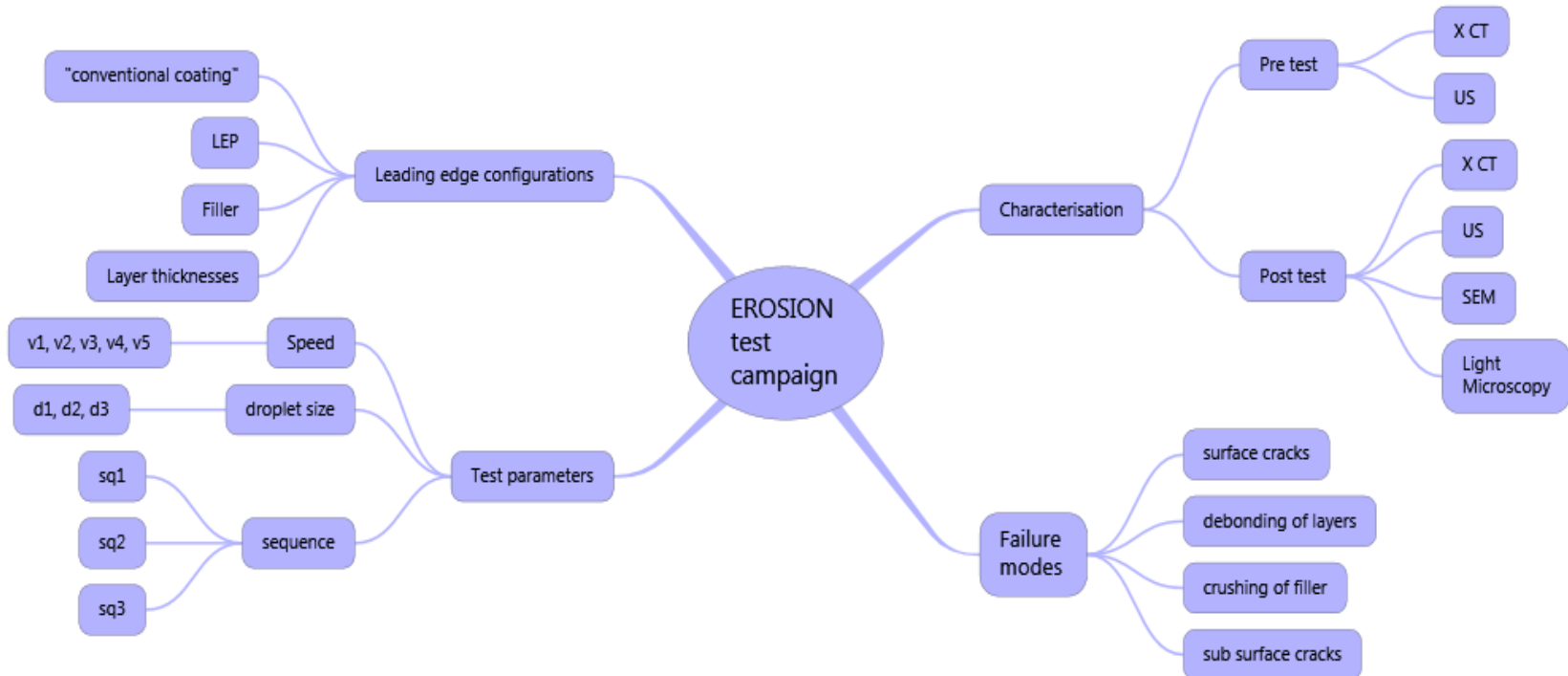
Rain erosion analysis

The initial test matrix is planned to provide life time curves for two different sizes of droplets in the rain field.

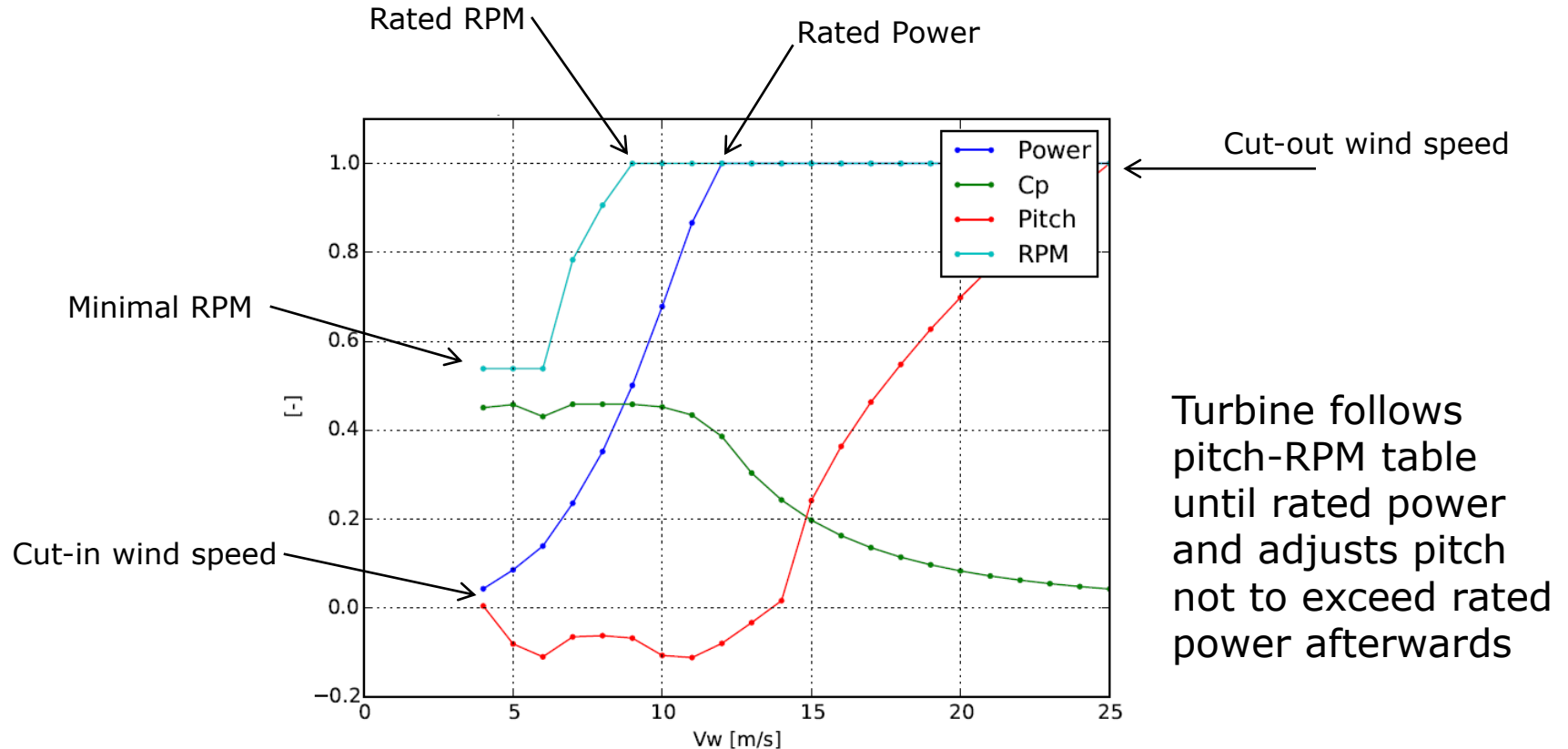
The damages of the specimens will be characterized using:

- microscopies
- X-ray tomography
- ultrasonic scanning
- visual inspection using the CCD camera

Rain erosion specimen testing map



Control of turbine

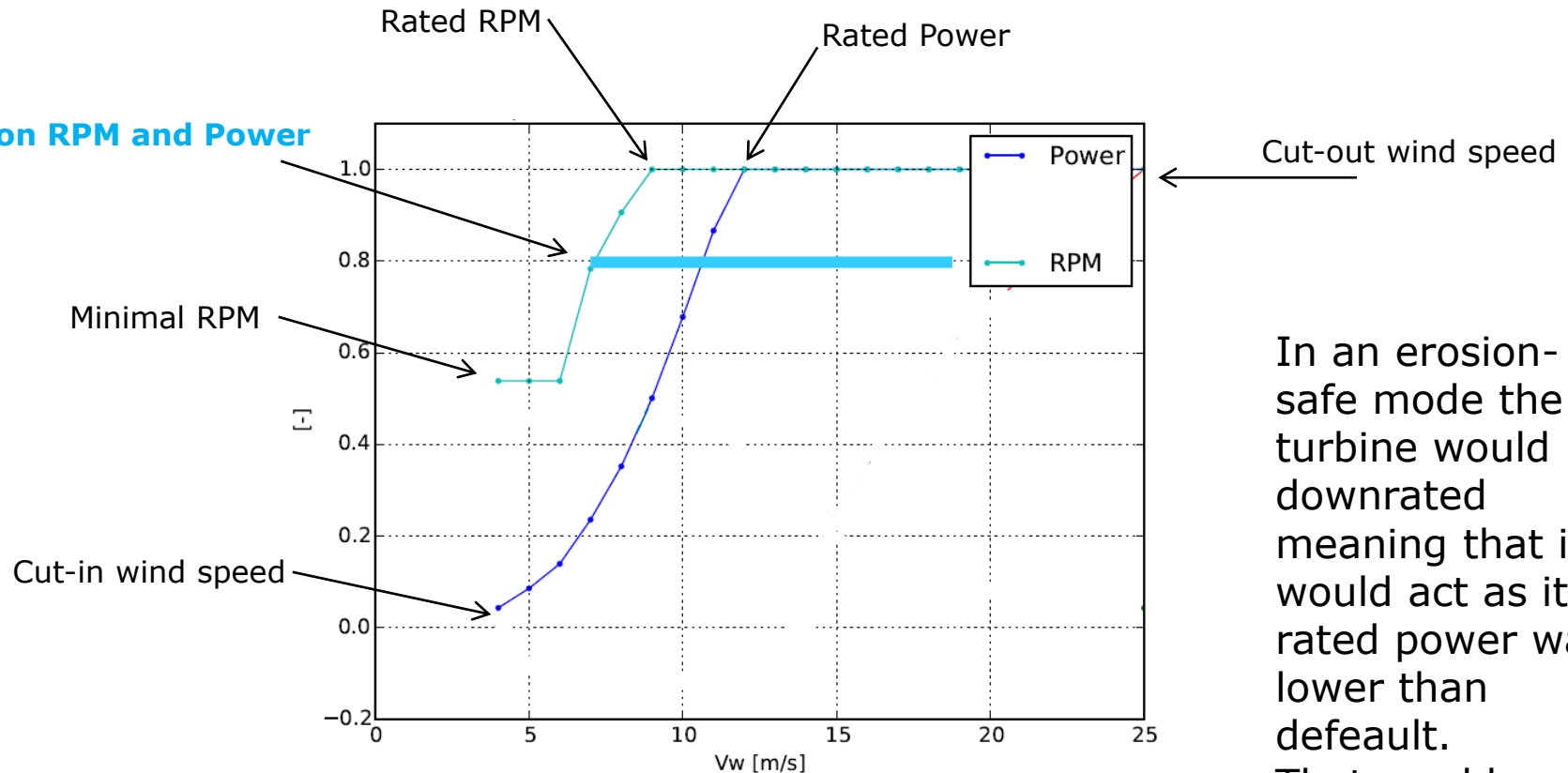


Turbine follows pitch-RPM table until rated power and adjusts pitch not to exceed rated power afterwards

$$\text{Power} = \text{Torque} * \text{Rotational_Speed}$$

How could erosion-safe mode look like?

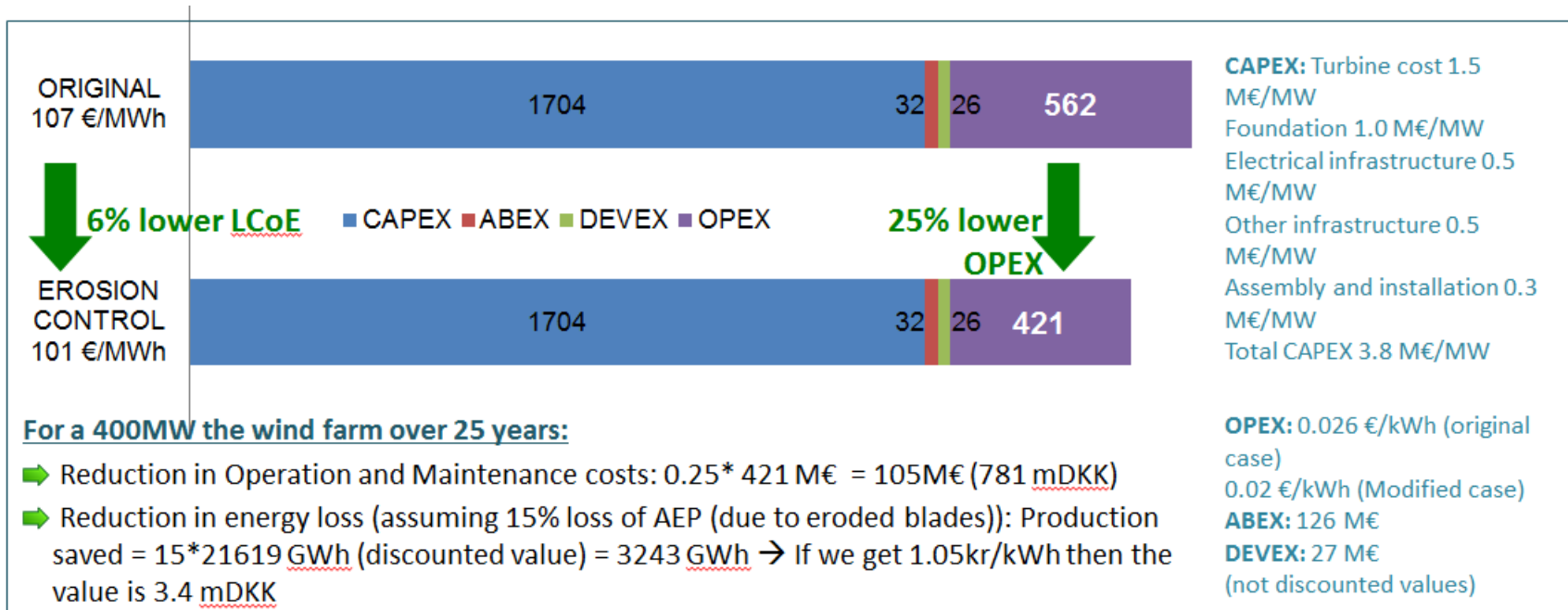
"Lid" on RPM and Power



In an erosion-safe mode the turbine would be downrated meaning that it would act as its rated power was lower than default. That would effectively decrease the rated RPMs.

$$\text{Power} = \text{Torque} * \text{Rotational_Speed}$$

The business case using MEGAVIND calculator



Next steps

Precipitation data collection during next one year

First tests in rain erosion tester and analysis of damage

Preparing field tests for control run

