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)

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DTU Wind Energy
Department of Wind Energy

EROSION

Wind turbine blade erosion: Reducing the largest uncertainties

DTU Wind Energy
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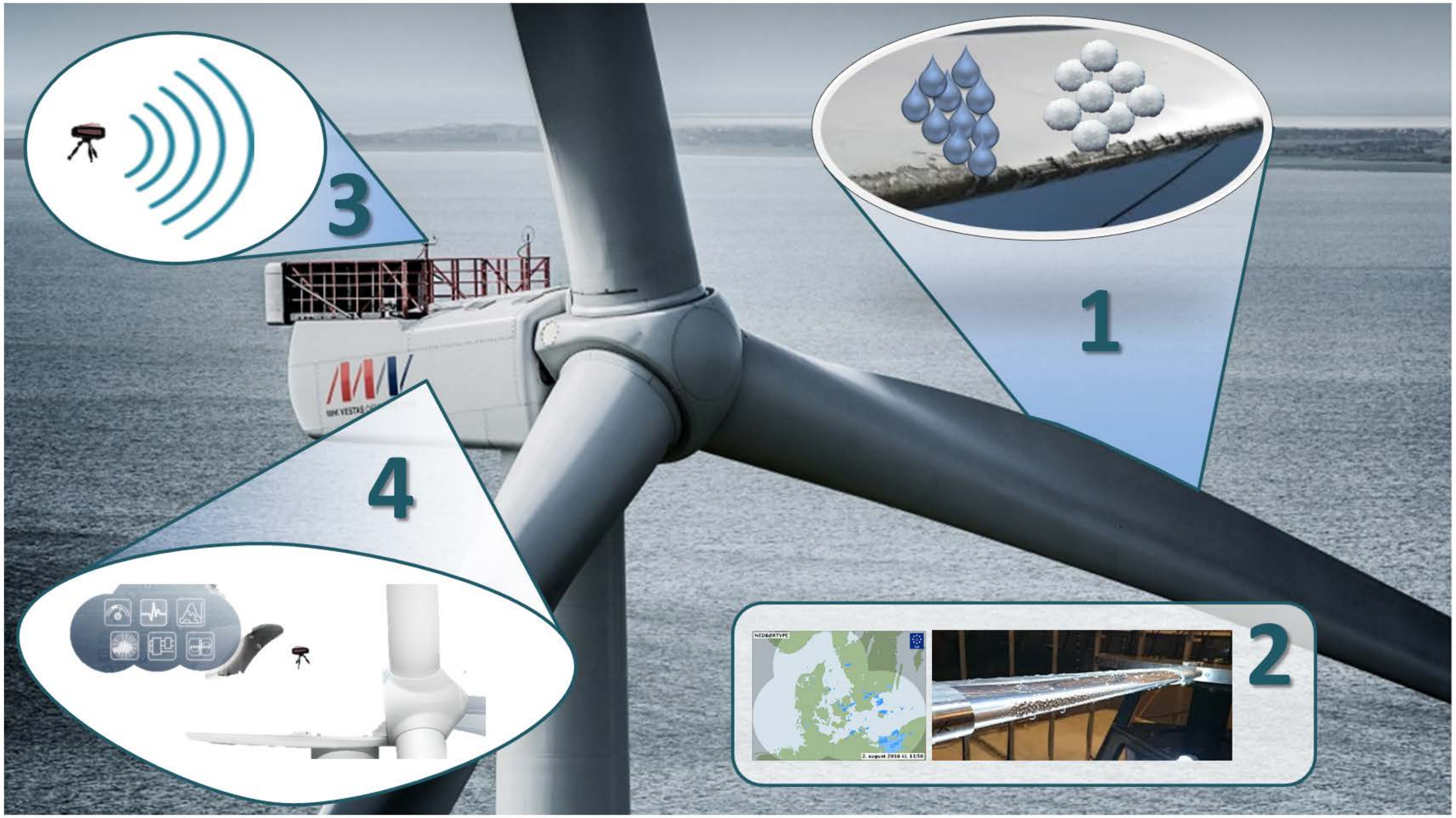

1. **Research hypothesis:** Erosion damage is mainly generated during heavy precipitation (big drops of rain or hail), which occurs in a very little fraction of the turbines operation time. By reducing the tip speed of the blades in these few hours a significant extension of the leading edge lifetime 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.

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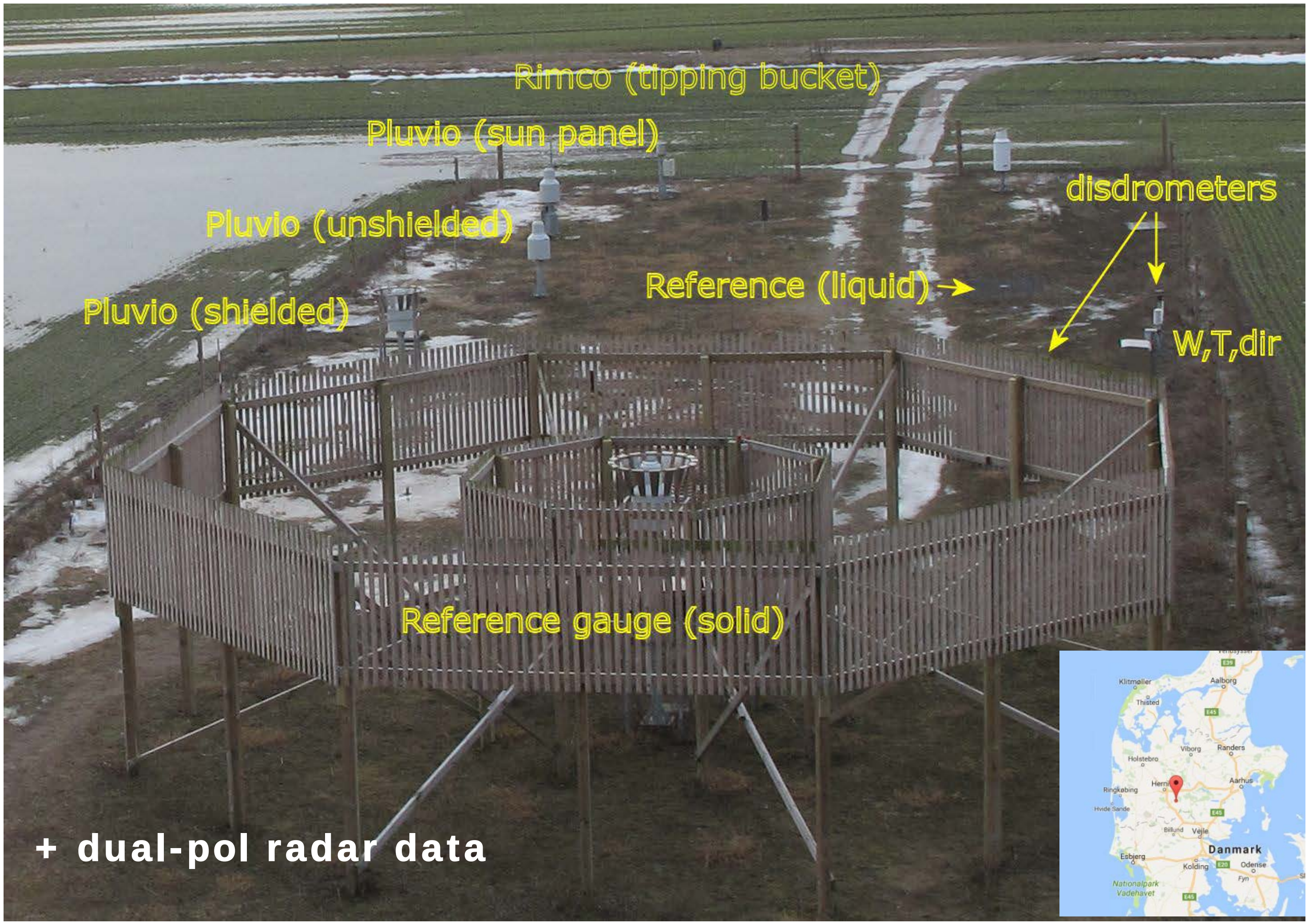
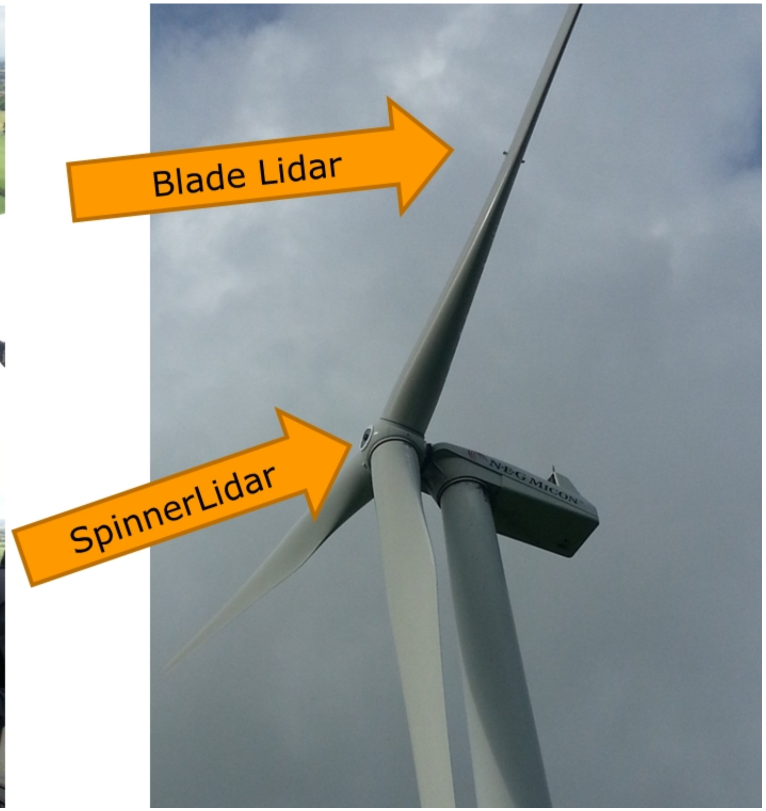
Validation of instruments and various experiments at DMI station
Data record available from Voulund test field (HOBE) 2012-now



Lidars at wind turbines



Turbine-mounted SpinnerLidar and blade-mounted Lidics 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 1.5μm 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.

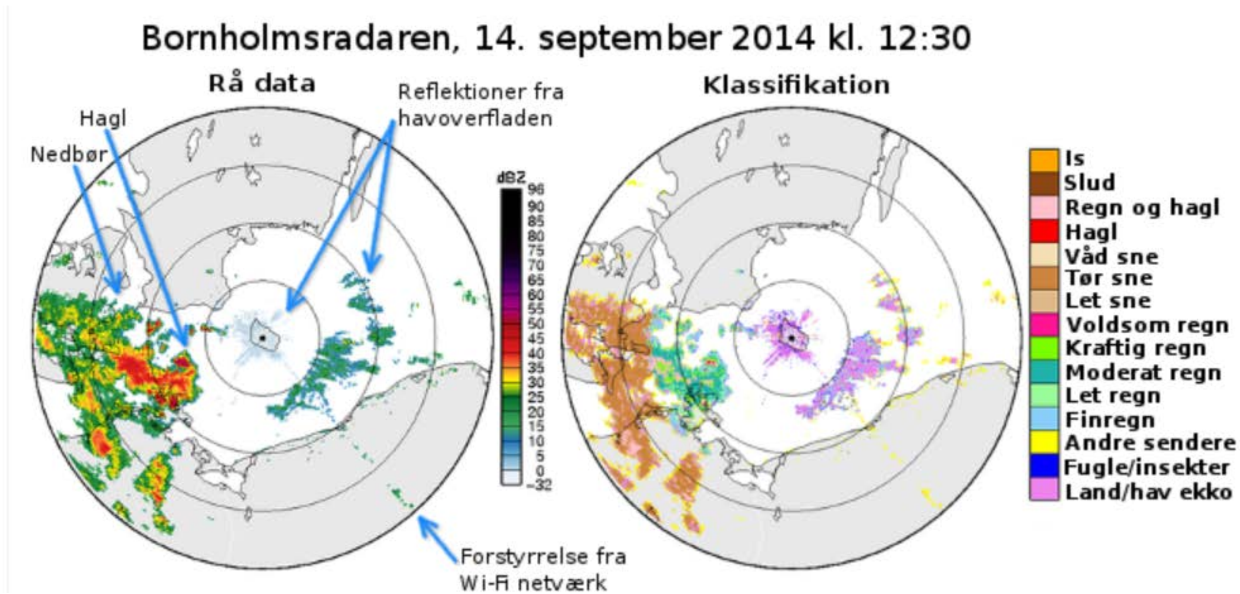
Radar reflection method to measure velocity on hydrometeors by 24-GHz-Doppler radar.

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

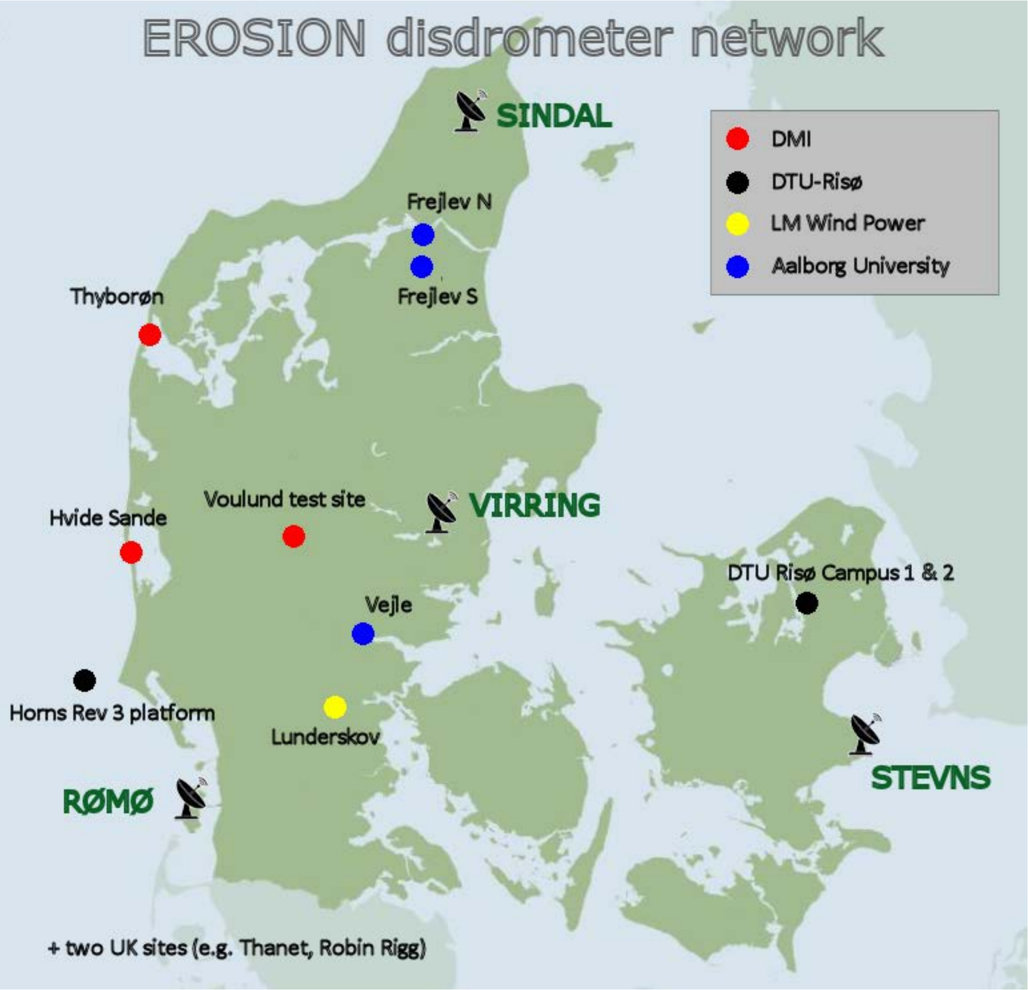
https://www.lufft.com/products/precipitation-sensors-287/ws100-radar-precipitation-sensor-smart-disdrometer-2361/

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

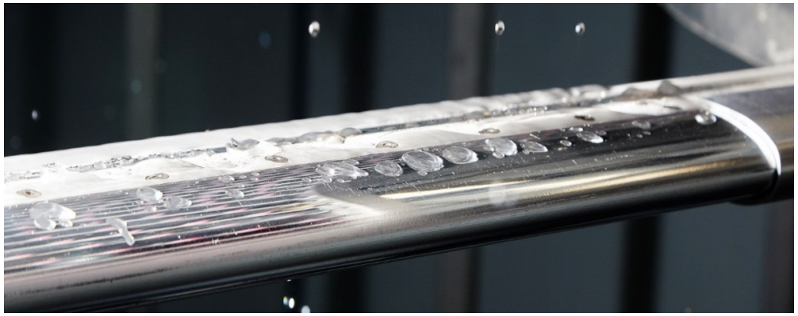
Main Concepts of Rain Erosion Testing

- 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

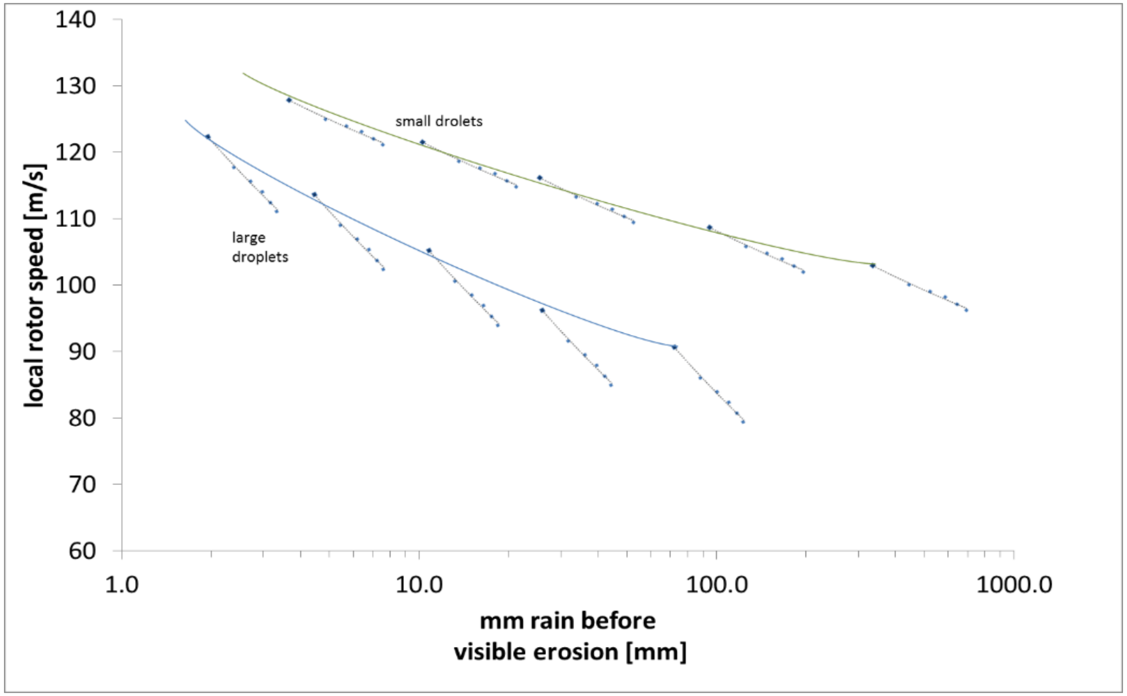
Rain erosion testing



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

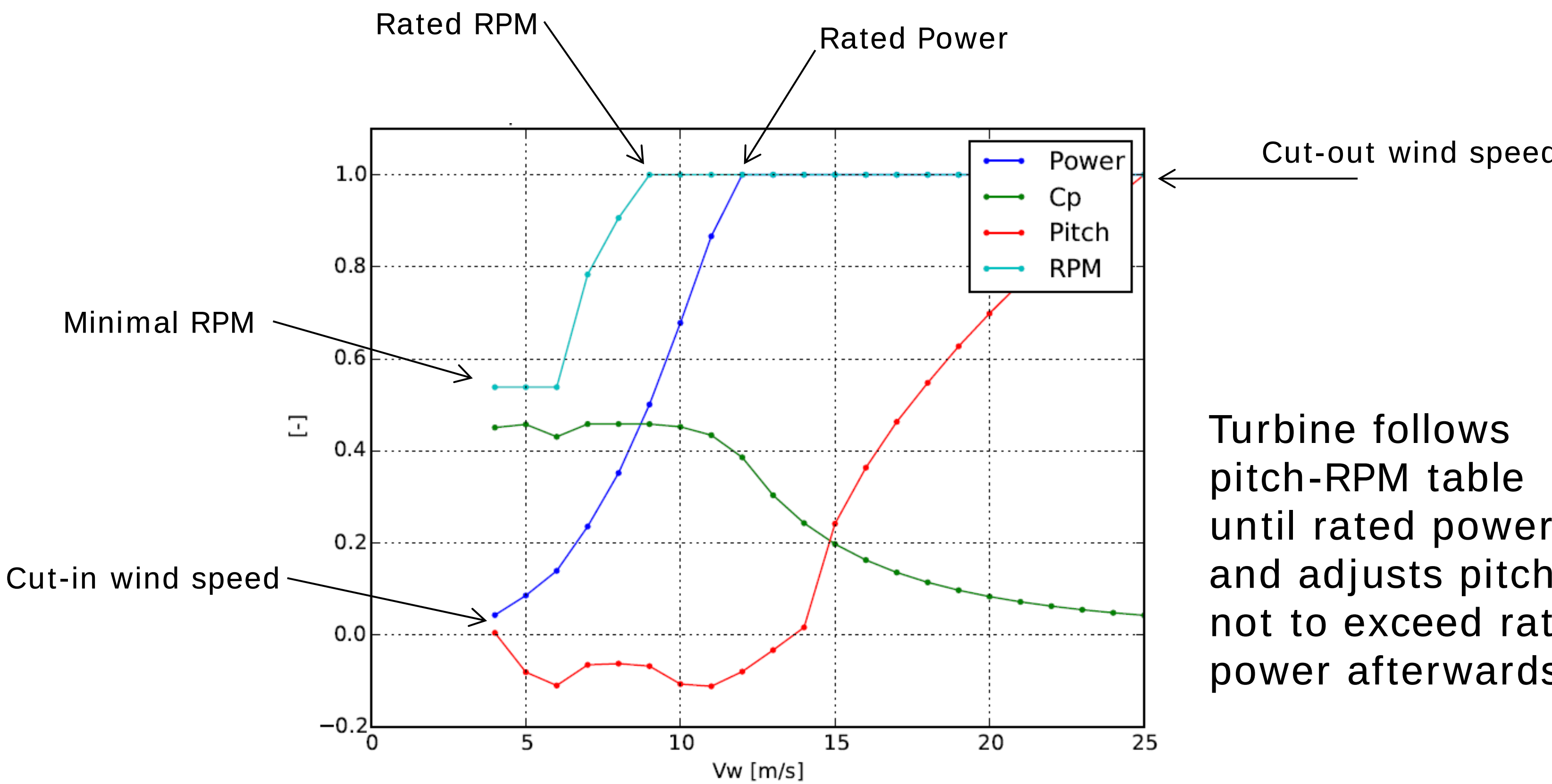
The initial test matrix is planned to provide life time curves for two different sizes of droplets in the rain field.

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

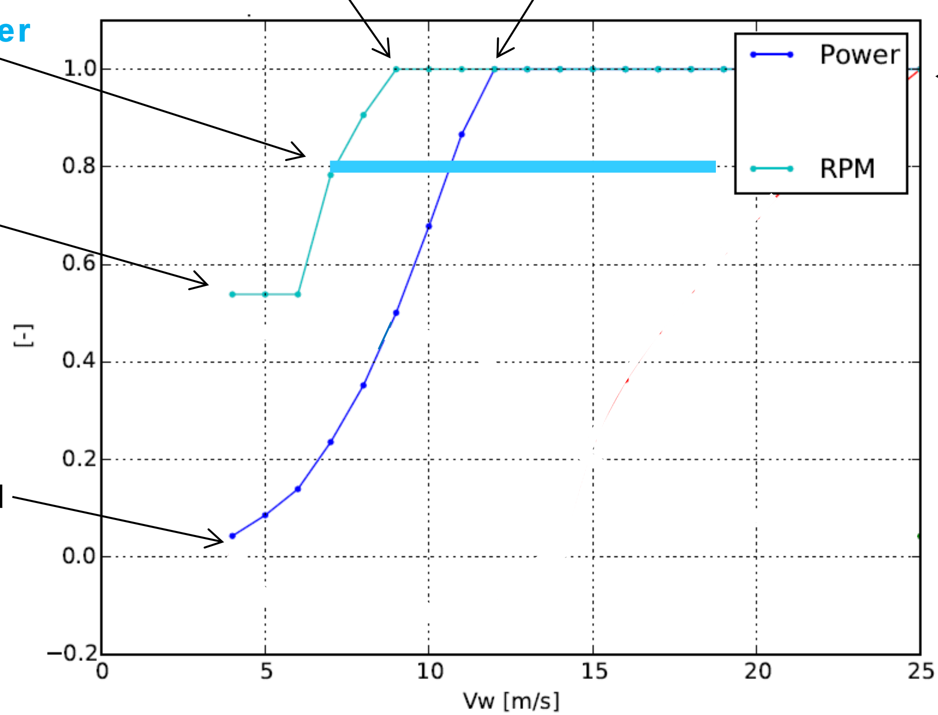
Control of turbine



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

Power = Torque * Rotational_Speed

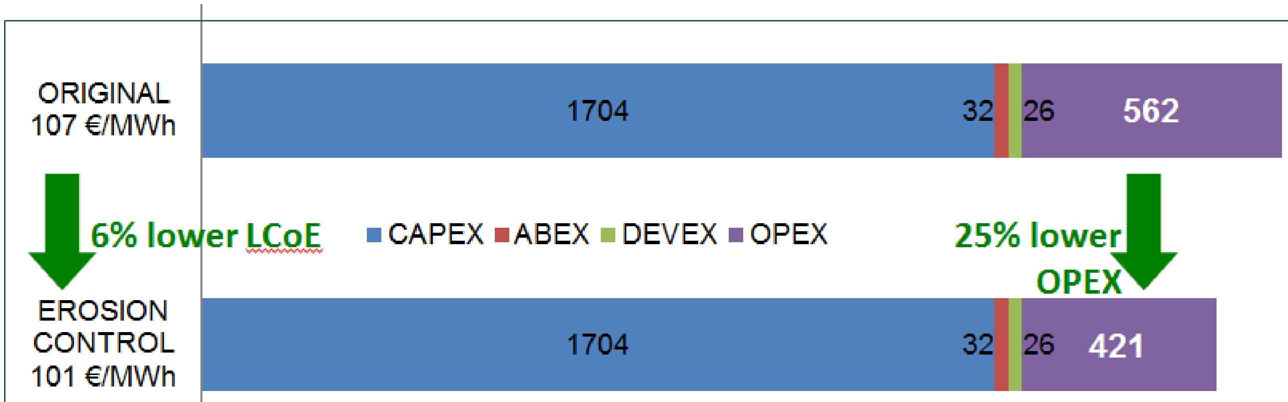
How **could erosion-safe mode** look like?



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

Power = Torque * Rotational_Speed

The business case using MEGAVIND calculator



CAPEX: Turbine cost 1.5 M€/MW
Foundation 1.0 M€/MW
Electrical infrastructure 0.5 M€/MW
Other infrastructure 0.5 M€/MW
Assembly and installation 0.3 M€/MW
Total CAPEX 3.8 M€/MW

OPEX: 0.026 €/kWh (original case)
0.02 €/kWh (Modified case)
ABEX: 126 M€
DEVEX: 27 M€
(not discounted values)

<u>**For a 400MW the wind farm over 25 years:**</u>

- Reduction in Operation and Maintenance costs: 0.25* 421 M€ = 105M€ (781 mDKK)
- Reduction in energy loss (assuming 15% loss of AEP (due to eroded blades)): Production saved = 15*21619 GWh (discounted value) = 3243 GWh → If we get 1.05kr/kWh then the value is 3.4 mDKK

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


Thank you