Wind and rain climate in offshore wind farms including energy production and leading edge erosion perspectives

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Content

• Offshore wind farms and motivation on rain erosion research

• Observation of rain drop sizes

• Rain and wind statistics

• Erosion safe mode control from simulation

• Summary
Offshore wind farms in Northern Europe

Source: https://www.4coffshore.com/offshorewind/
Motivation
I will focus on rain

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.
Denmark with disdrometer observations stations

• Map of stations
Disdrometer type in EROSION project

• Disdrometers are based on an optical principle (laser) to measure drop size distribution and velocity of precipitation particles

• PARSIVEL² (PARticle SIze and VELocity) from OTT

Löffler-Mang and Joss (2000)
Disdrometers at Risø Campus

123 m tall meteorological mast
Risø Campus disdrometer data one month

Example of data from three month:
1 to 30 July 2019 measured with a time resolution of 1 minute:

• Rain intensity [mm/h]
• Rainfall kinetic energy [Jm⁻²h⁻²]
• Size-velocity histogram / drop-size distribution (DSD)
Rain intensity observed at Risø Campus (1 year 3 months)
Kinetic energy from rain observed at Risø Campus

Start: 2018-05-01 00:01:00, end: 2019-07-30 12:47:00

Kinetic Energy [J m⁻² h⁻¹]
Size-velocity diagram of rain observed at Risø Campus
Event with high rain intensity at Risø campus
Voulund: Minutes with rain, rain amount, rain kinetic energy as function of wind speed (6 years)

Station: Voulund; Data source wind speed: DMI – Danish Meteorological Institute
What does it mean for wind production?

Example of Erosion Safe Mode Control
Control strategies

Control strategy 1: No reduction 90 m/s
Control strategy 2: Little reduction 80 m/s and 70 m/s
Control strategy 3: Much reduction 55m/s, 65m/s and 70m/s

Vestas V52 850 kW pitch regulated variable speed and modified rotation speed to make it consistent with larger turbines.
Control strategy 1: No reduction (NORMAL)

Life time of the blade leading edge with **no reduction** of the tip speed.

<table>
<thead>
<tr>
<th>Rain intensity [mm/hr]</th>
<th>Droplet size [mm]</th>
<th>Percent of time [%]</th>
<th>Hours pr year [hrs/year]</th>
<th>Blade tip speed [m/s]</th>
<th>Hours to failure [hrs]</th>
<th>Fraction of life spent pr year [%]</th>
</tr>
</thead>
<tbody>
<tr>
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<td>0.0</td>
</tr>
</tbody>
</table>

Sum of fractions [%]: 64

Expected life [years]: 1.6
Control strategy 2: **Little reduction**

**Life time of the blade leading edge with reduction of the tip speed to 70m/s and 80m/s.**

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**Sum of fractions [%]:** 9.6

**Expected life [years]:** 10.4
Control strategy 3: **Much reduction**

Life time of the blade leading edge with **reduction of the tip speed to 55m/s, 65m/s and 70m/s.**

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Sum of fractions [%]: 0.9

Expected life [years]: 107

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**Control strategy 3: Much reduction**

Life time of the blade leading edge with **reduction of the tip speed to 55m/s, 65m/s and 70m/s.**

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Sum of fractions [%]: 0.9

Expected life [years]: 107
Summary on control

<table>
<thead>
<tr>
<th>Control strategy</th>
<th>Loss in AEP relative to idealized case (%)</th>
<th>Saved cost on repair relative to idealized case (%)</th>
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<tbody>
<tr>
<td>Control 1</td>
<td>3.2</td>
<td>12.0</td>
</tr>
<tr>
<td>Control 2</td>
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<tr>
<td>Control 3</td>
<td>0.7</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Assumed costs:

- Electricity price 50 EUR per MWh\(^{-1}\)
- Repair cost 20000 EUR/rotor
- Inspection cost 1500 EUR/rotor
Reading:

Wind Energ. Sci., 3, 729–748, 2018
https://doi.org/10.5194/wes-3-729-2018
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Extending the life of wind turbine blade leading edges by reducing the tip speed during extreme precipitation events

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Summary

• Rain cause leading edge erosion

• It cost much in maintenance to repair blades offshore

• Need to observe and quantify rain at wind farm locations

• Suggestion to use erosion safe mode control
Acknowledgements

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• grant 6154-00018B for the project EROSION.

www.rain-erosion.dk

Innovation Fund Denmark