EFFECT OF CURTAILMENT SCENARIOS ON WTG SUPPORT STRUCTURE LOADS AND LIFETIME

A DATA-DRIVEN LIFETIME ASSESSMENT

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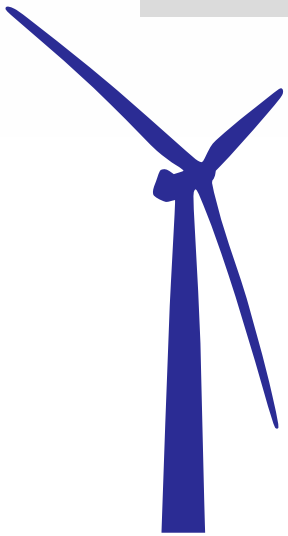
WindEurope Annual Event 2023
Conference session: Innovative methods to make the most out of your operational data



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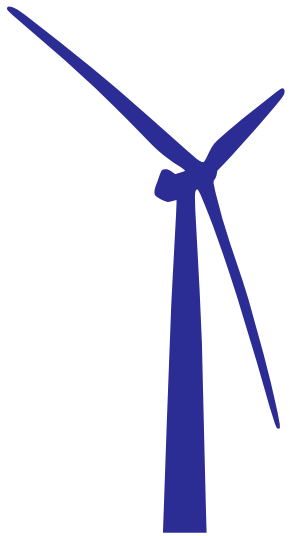
THE EFFECT OF CURTAILMENT ON STRUCTURAL LIFETIME

CHAPTERS

1. Curtailment, its consequences and objective of this work
2. Data-Analysis methodology
3. Data-driven results
4. Conclusions and outlook

Curtailment, its consequences and objective of this work



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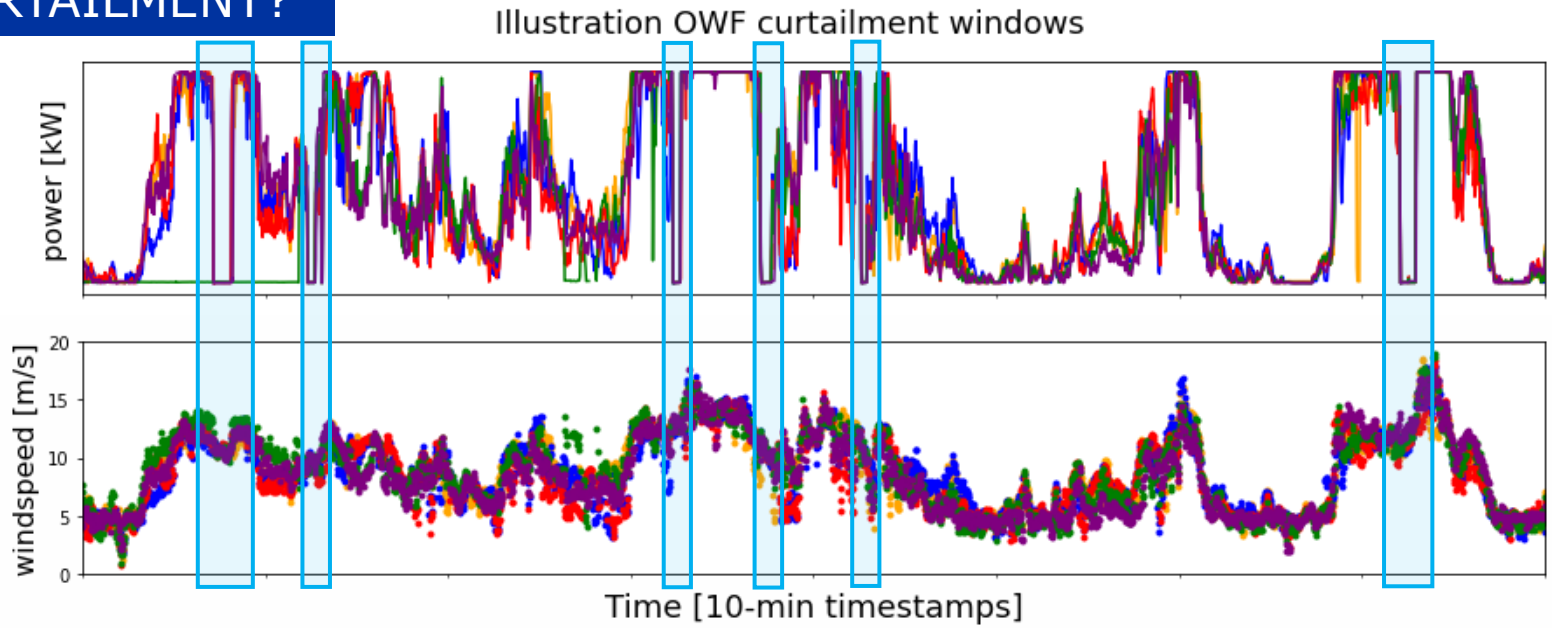
CURTAILMENT AND ITS CONSEQUENCES

WHAT IS CURTAILMENT?

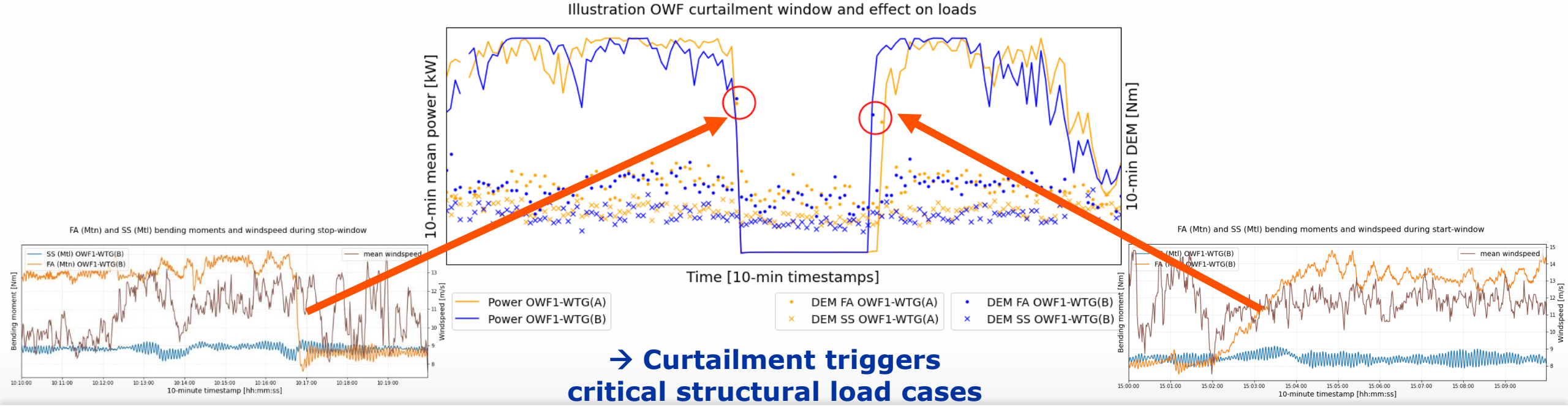


- Forced de-rated power production over the entire OWF at favourable wind conditions
- A tool for the Balance Responsible Party (BRP)
- (offshore) wind has the advantage to be a flexible energy asset in the grid.
  → Curtailment of OWF's is expected to rise in the future

CURTAILMENT AND ITS CONSEQUENCES

CONSEQUENCES OF CURTAILMENT?

- Consequences of curtailment
  - *Reduced power production*
  - Increased **standstill** period: a driving load case in modern WTG support structure designs !
  - Increased number of **transitions** between operational conditions: event load cycles !



→ Curtailment triggers critical structural load cases

CURTAILMENT AND ITS CONSEQUENCES

OBJECTIVE OF THIS WORK

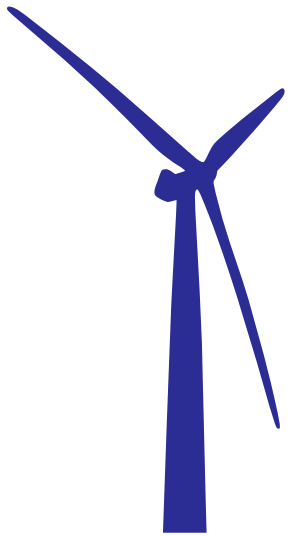
- Curtailment triggers **critical structural load conditions**
  - **Standstill** conditions are driving load cases in modern WTG support structure designs
  - **Transitions** between operational conditions are causing high fatigue loads

    → **The impact on structural lifetime to be investigated.**

Objectives of the study:

- Investigation of the impact of **increased frequency of transitions** on structural lifetime
- Data-driven insights towards decision support for a **long-term curtailment strategy**

Data-Analysis methodology



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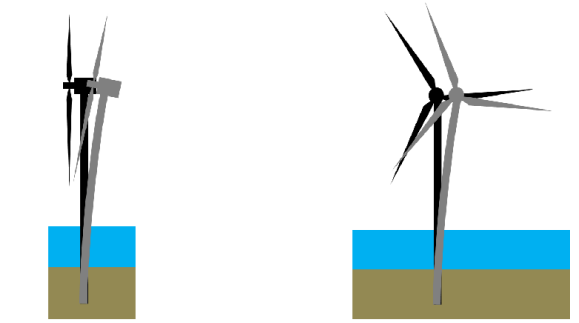
DATA-ANALYSIS METHODOLOGY

THE DATA

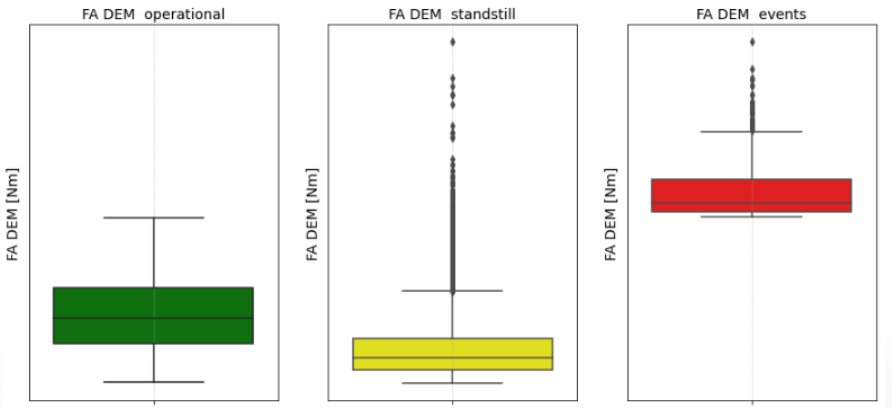
- 1 year of **SHM data** collected from 4 turbines at 2 wind farms
  - Load monitoring at interface level: 6 strain gauges
  - 10-min Damage Equivalent Moment (DEM) derived in fore-aft & side-side directions



a) Fore-aft direction. **(b)** Side-side direction.

- Data **binning** approach: based on **operational condition** in normal and curtailed operating regime (1D)
  - Operational
  - Standstill
  - Transient (events)

- Allowing to assess probabilities and 10-min DEM's per operational condition
- Evaluated operational scenarios defined based on these



DATA-ANALYSIS METHODOLOGY

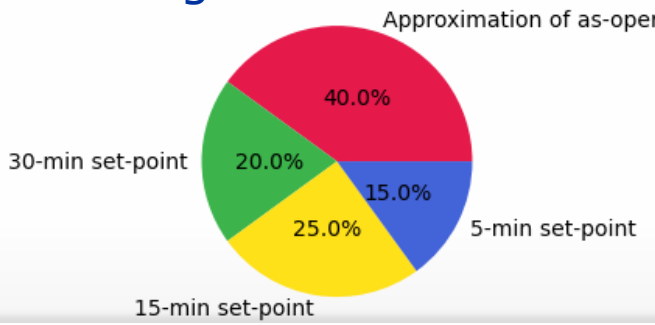
THE EVALUATED SCENARIOS

- **Approximated as-operated scenario**
- **3 Fictive scenarios with theoretical - rigid - curtailment regimes**
  - Comparable with OWF's as-operated scenario in terms of: operational and standstill time
  - Curtailment regimes **differ** in number of transitions due to curtailment based on power set-point time
    - 30-minutes
    - 15-minutes
    - 5-minutes

→ Probabilities of occurrence to every operational condition can be assigned

- **Combination scenario**

→ Basis for long-term curtailment strategy ?



DATA-ANALYSIS METHODOLOGY

THE LOAD AND LIFETIME IMPACT ASSESSMENT

- **Total DEM per scenario** calculated by combining:
  - **Probability of occurrences** of the operational condition bins
  - **Representative DEM** in that bin (uniform P50 approach chosen for the published results)

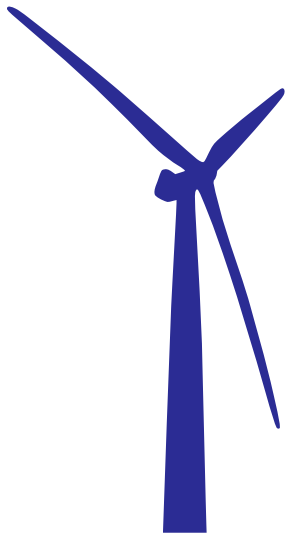
$$DEM_{tot,scen} = \sqrt[m]{\sum_{bin,0}^{Number\ of\ bins} probability\ of\ occurance_{\ bin,i} \cdot DEM_{P50,bin,i}^{m}} \quad (1)$$

- **Lifetime impact assessment**:
  - Comparing DEM's to a reference DEM

$$Lifetime\ Impact\ Factor = \left(\frac{DEM_{total,scenario\ 30-\min\ set\ point\ time}}{DEM_{total,scenario}}\right)^{m} - 1 \quad (4)$$

  - Factor = 0 No impact on lifetime compared to the reference
  - Factor < 0 Negative impact on lifetime consumption, lifetime – factor%
  - Factor > 0 Positive impact on lifetime consumption, lifetime + factor%

Data-driven results



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DATA-DRIVEN RESULTS

THE LOAD AND LIFETIME IMPACT ASSESSMENT

- **As-operated OWF1 vs OWF2** compared to a reference scenario with 30-min set-point curtailment regime
- More significant difference between as-operated WTG(A) and WTG(B) in OWF2
- **Detrimental impact of more flexible curtailment regimes** is clear (20-30% and 50-75% impact on lifetime)
- The **combination scenario** indicated combining flexible curtailment regimes is feasible with mitigated impact on lifetime
  → Data-driven decision support for a curtailment strategy

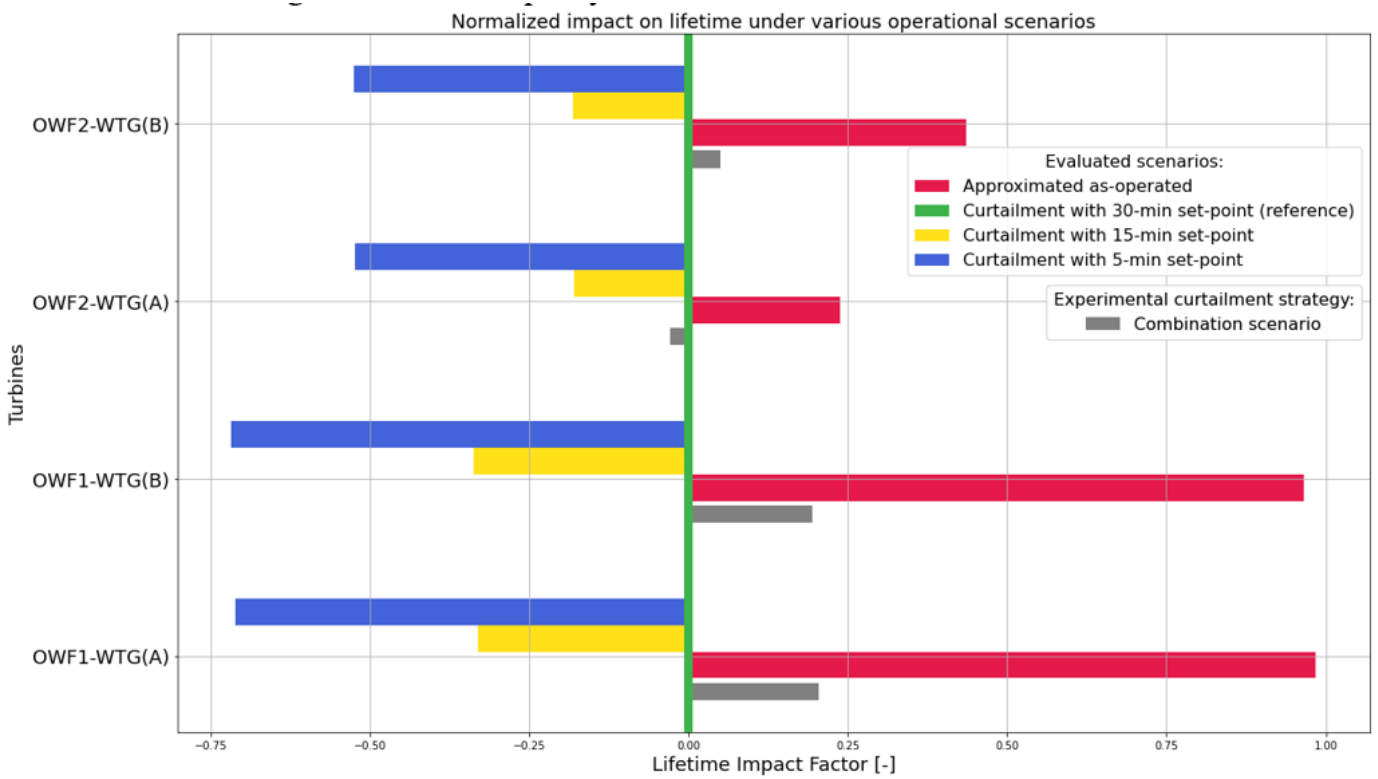
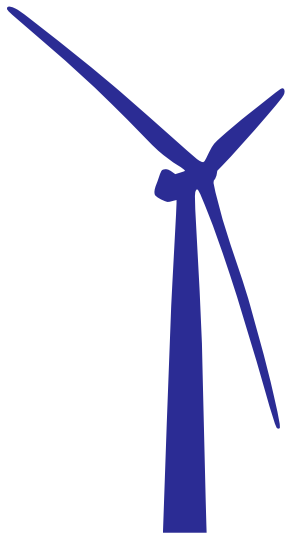


Figure 3: Data-driven lifetime impact assessment for various operational scenarios

Conclusion and outlook



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CONCLUSIONS AND OUTLOOK

CONCLUSIONS

- The **long-term impact** on structural lifetime due to curtailment **cannot be neglected**
  - Increased number of events
  - Longer standstill
- **Data-driven insights can support in decision making**
  - **Fictive operational scenarios** assessed with **real-world load measurements**
  - Combination of theoretical scenarios → **long-term curtailment strategy**

A long-term curtailment strategy is to be considered to avoid excessive structural lifetime consumption due to a short-term curtailment vision.

CONCLUSIONS AND OUTLOOK

OUTLOOK

Research towards data-driven lifetime assessment:

- Refinement of binning approach
- Inclusion of detrimental effect of increased standstill period and side-side loads
- More variation in curtailment regimes
- Comparing with the as-designed conditions for foundation lifetime assessment

The conversation on curtailment

- Expected to remain of topic of discussion
- Triggering cooperation between BRP’s and OWF’s

ACKNOWLEDGEMENTS

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THANK YOU

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