ANALYSIS OF LEADING EDGE EROSION IMPACT ON THE DESIGN AND PERFORMANCE OF WIND FARM FLOW CONTROL

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01

INTRODUCTION

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INTRODUCTION

- Leading edge erosion (LEE) → Impact on wind turbines operation and maintenance cost
- Offshore sites are more sensitive to LEE occurrence:
  - Higher average wind speeds
  - More rainy conditions
- LEE causes a loss of aerodynamic efficiency at below rated wind speeds
- This loss also affects the flow interaction with the rest of wind turbines in the wind farm (thrust coefficient) [1]
- It could also have an impact on wind farm flow control (WFFC) strategies
- **Objective: analyse the impact of LEE on WFFC strategies (wake steering in this case)**

Image from Vattenfall (https://group.vattenfall.com/)
Photographer: Christian Steiness

02
METHODOLOGY

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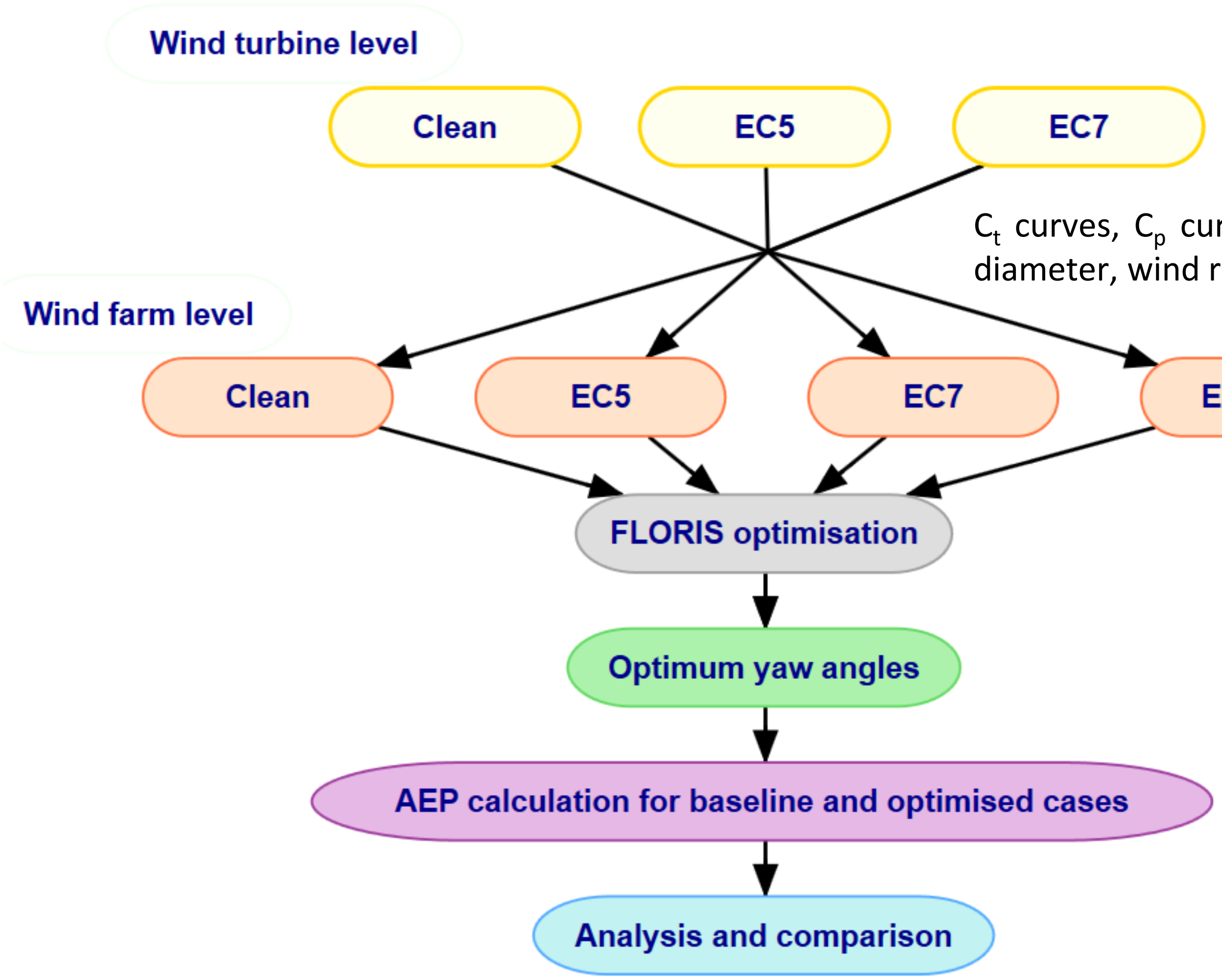
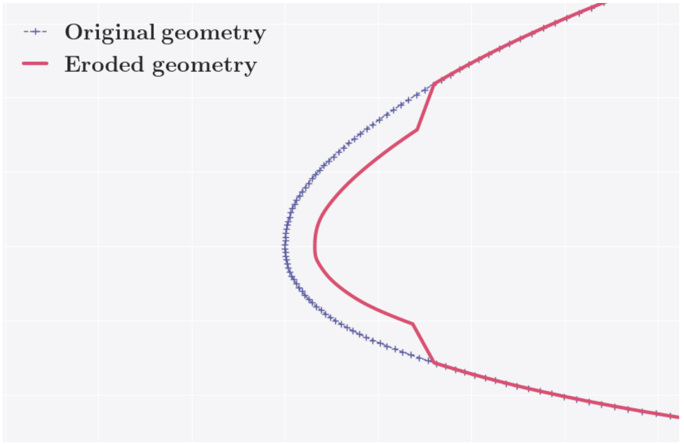
METHODOLOGY



Erosion categories

C_t curves, C_p curves, rotor diameter, wind rose…

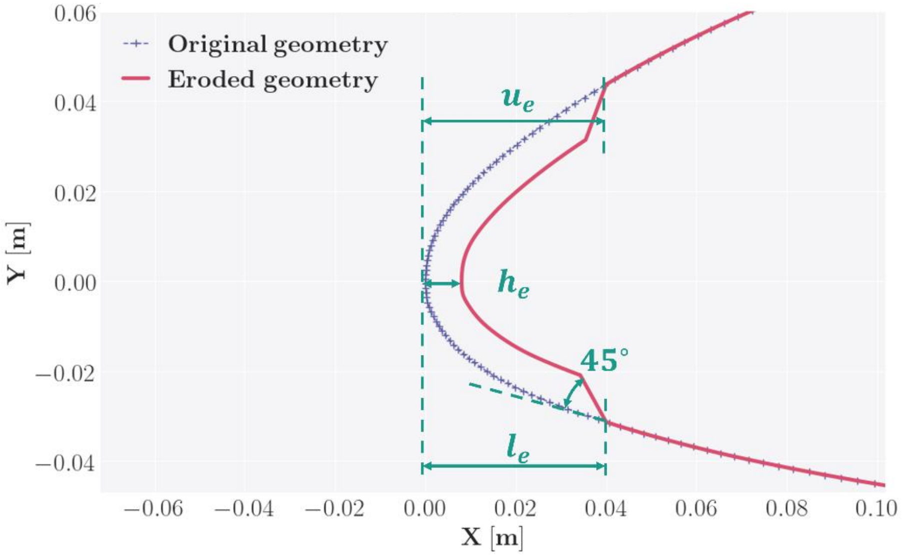


EC5/EC7: Combination of different erosion categories at the same wind farm. Unwaked wind turbines (in most probable wind directions) considered to be more eroded (EC5)

METHODOLOGY

- Erosion categories used (loss of material):
  - Last 30% of the blade with erosion [2, 3]
  - Constant erosion with blade length

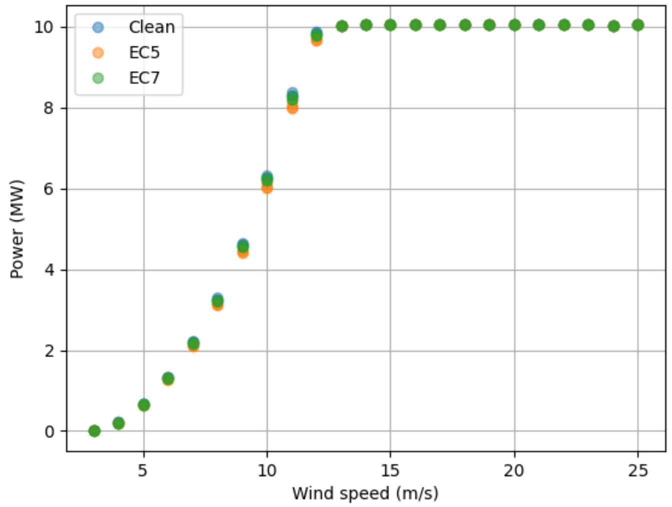
Erosion category	h_e [%c]	u_e [%c]	l_e [%c]	Max. efficiency $\frac{C_L}{C_D}$ loss [%]
5 (higher)	0.12	8	8	38.72
7 (lower)	0.12	5	5	22.47

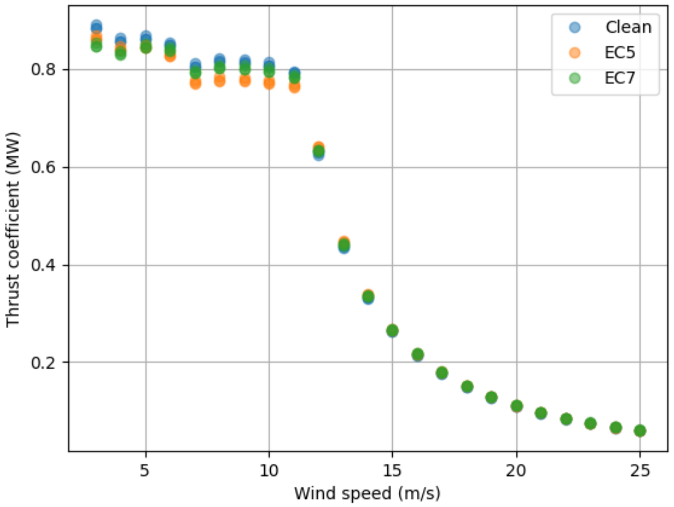


Polars obtained with OpenFOAM (CFD)

Polars used in OpenFAST

- Power and C_t curves for the selected erosions (inputs for FLORIS):





03

CASE STUDY

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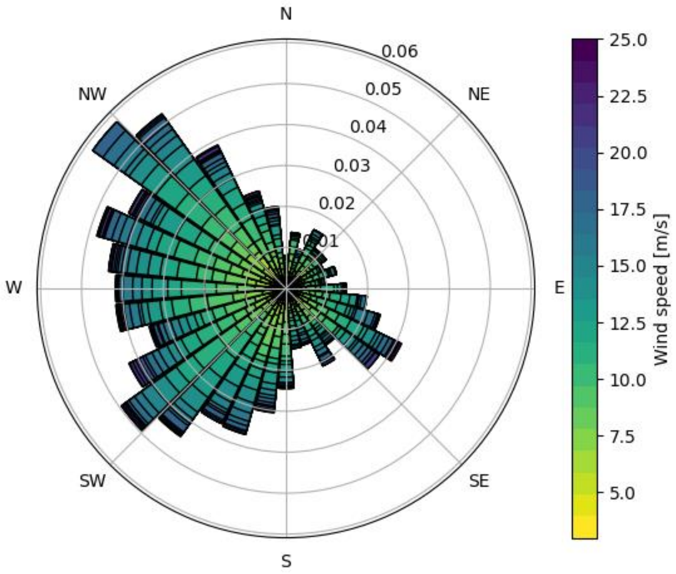
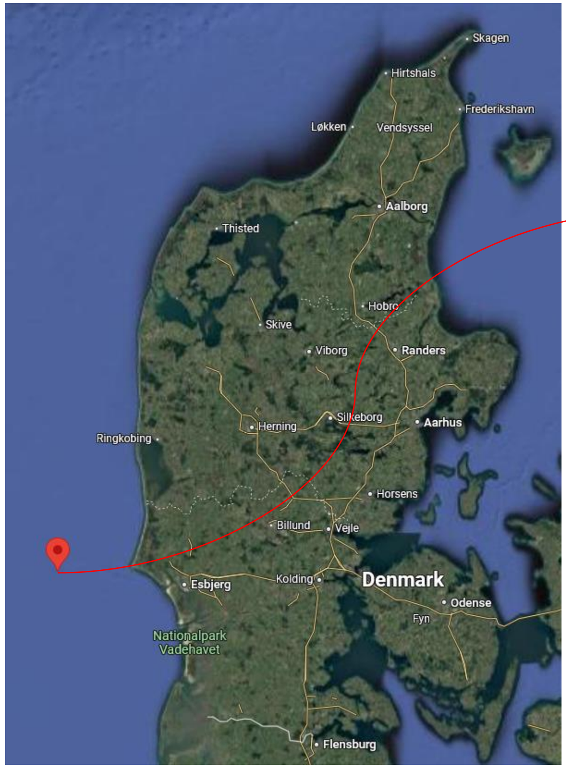
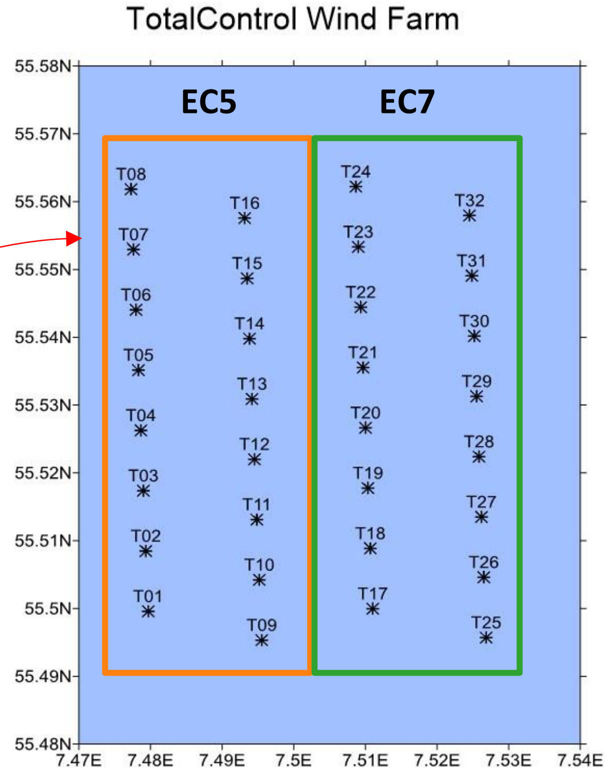
CASE STUDY

- Virtual wind farm: TotalControl Reference Wind Power Plant (32 wind turbines) [4]
- Wind turbine: DTU 10MW Reference Wind Turbine [5]
- Resource data extracted from [6, 7, 8]
- Eroded blade profile: FFAW3241
- Wind turbine modelling tool: OpenFAST [9]
- Wind farm modelling and optimisation software: FLORIS [10]

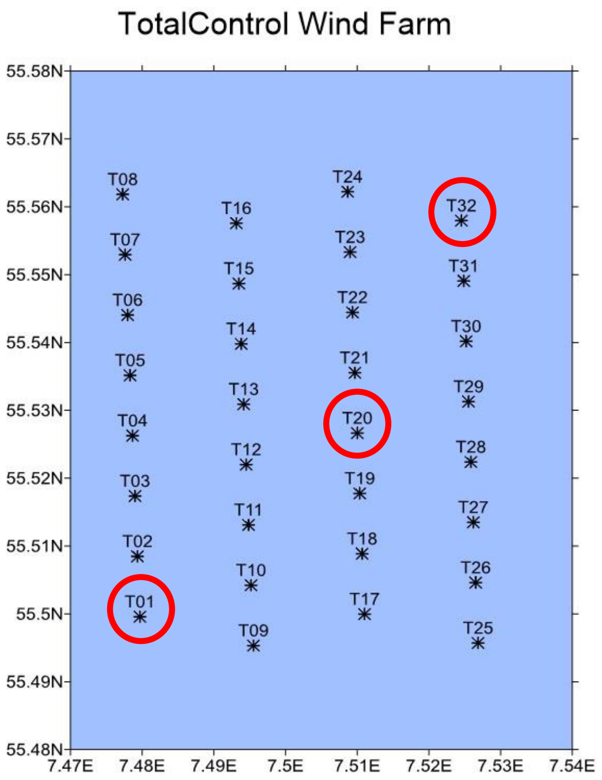


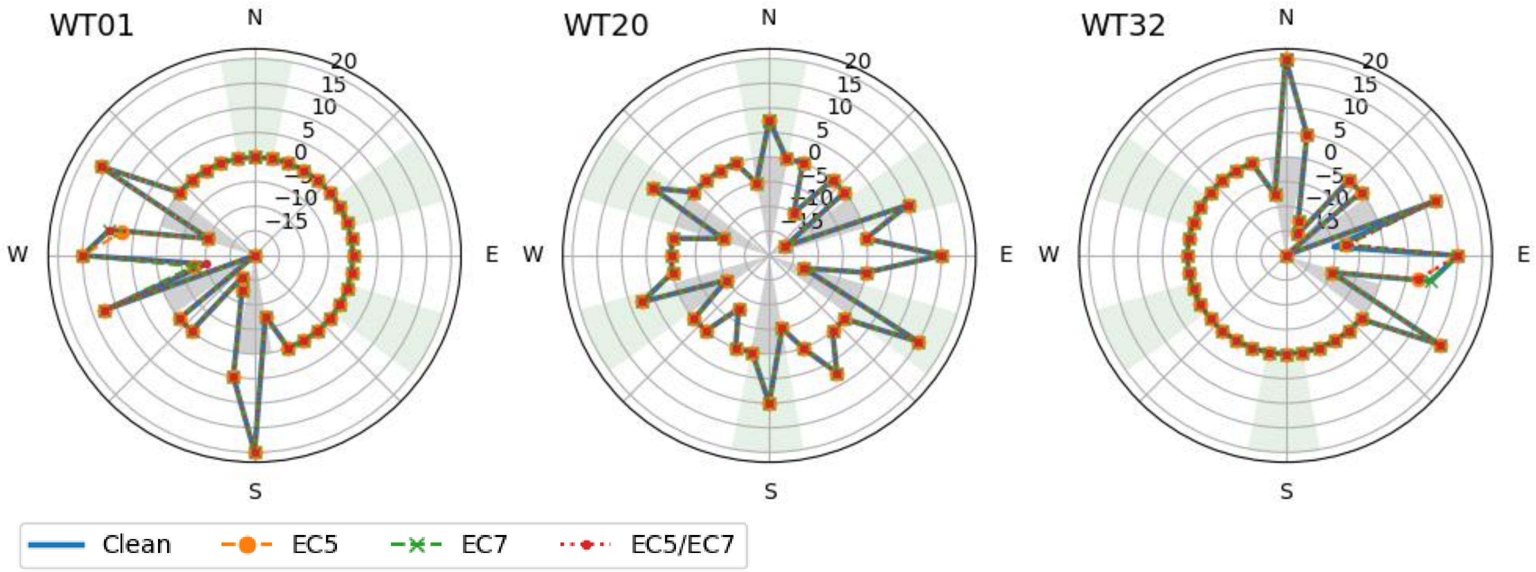




CASE STUDY

- Optimal yaw angles for 7 m/s wind speed:





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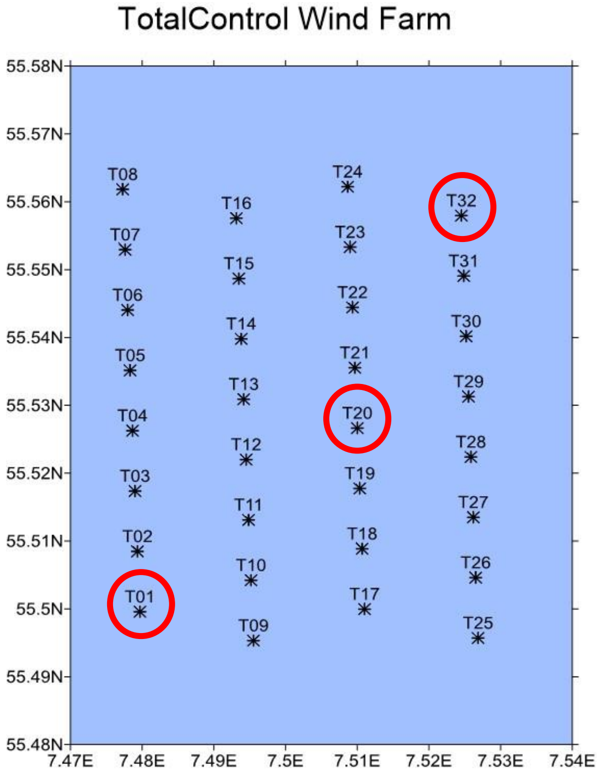
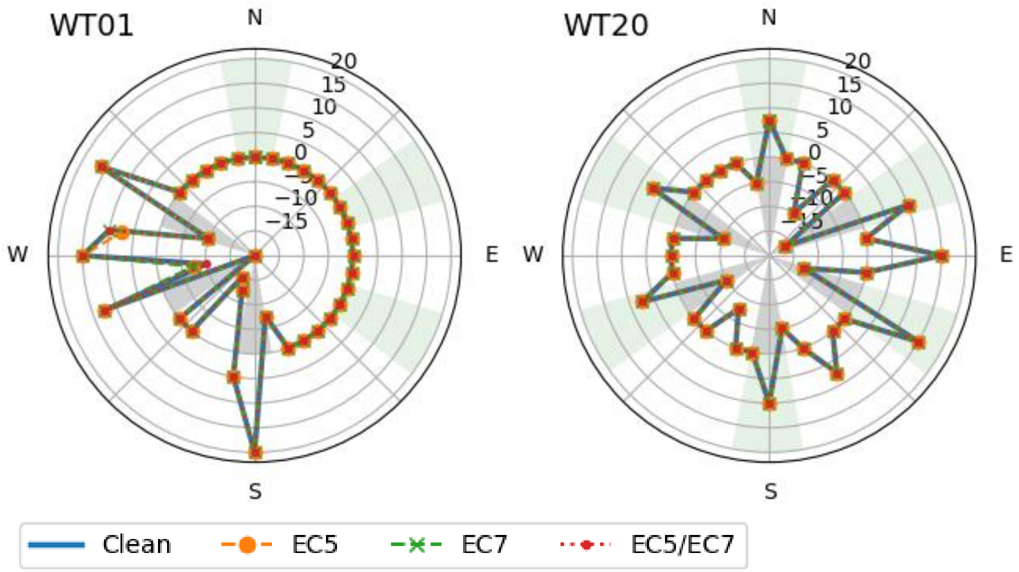
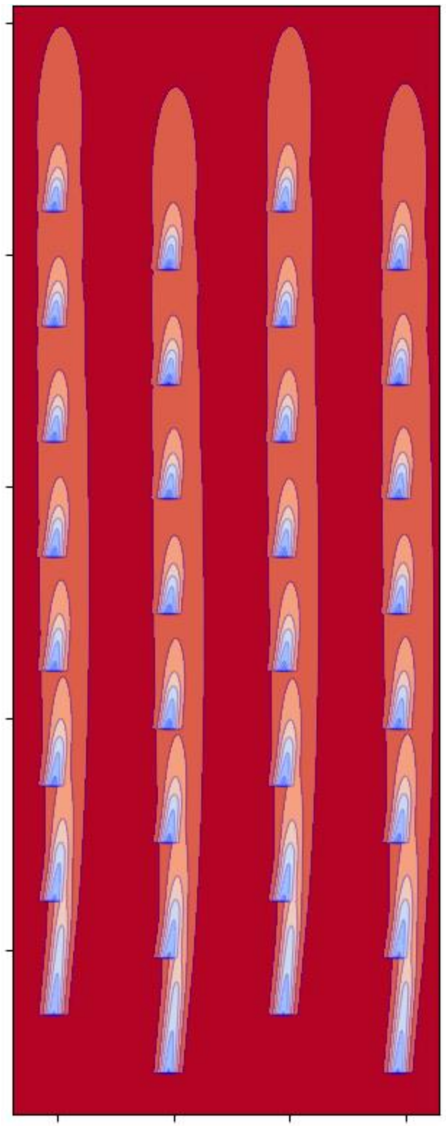
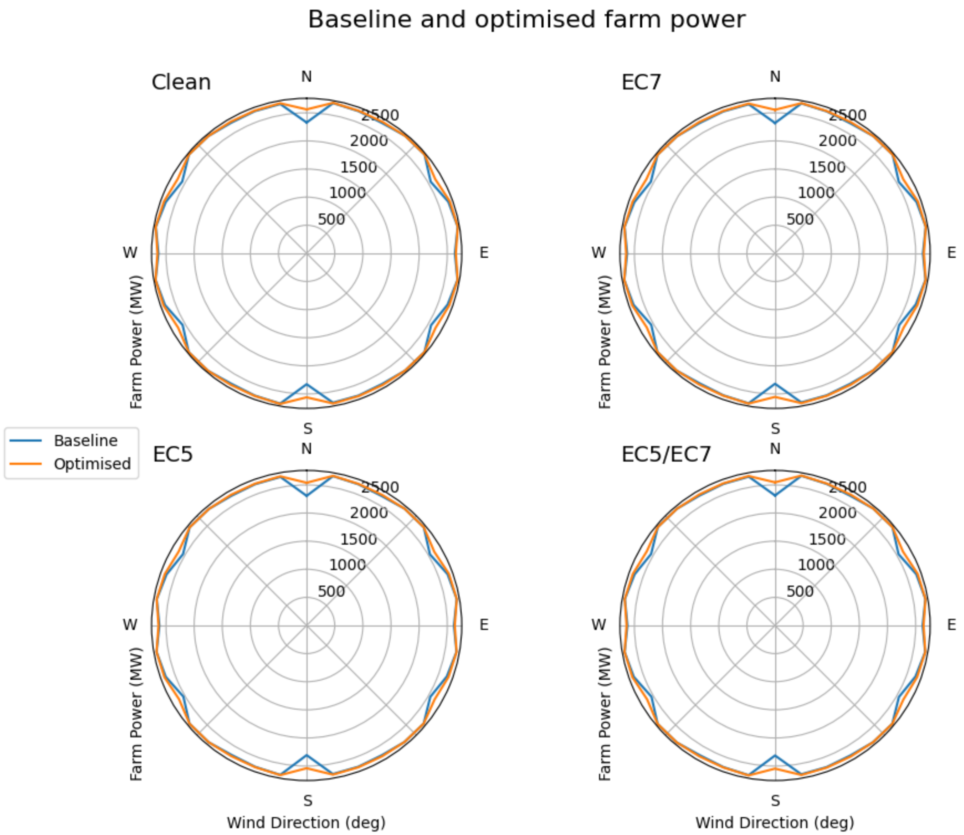






CASE STUDY



Wind farm erosion type	Baseline AEP [GWh]	Baseline AEP erosion loss [%]	Optimised AEP [GWh]	Optimised AEP erosion loss [%]
Clean	1623.73	**-**	1663.16	**-**
EC7 (less eroded)	1615.70	**0.49**	1654.55	**0.52**
EC5/EC7 (mixed)	1607.27	**1.01**	1645.28	**1.08**
EC5 (more eroded)	1598.52	**1.55**	1635.85	**1.64**

Wind farm erosion type	AEP loss due to wakes [%]	AEP gain from baseline to optimised [%]
Clean	**7.58**	**2.43**
EC7	**7.54**	**2.40**
EC5/EC7	**7.49**	**2.36**
EC5	**7.46**	**2.34**

Erosion ↑ ➢ Wakes ↓ ➢ AEP loss due to wakes ↓ ➢ AEP gain with optimisation ↓

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CONCLUSIONS

CONCLUSIONS

- Similar yaw setpoints for different erosions
- AEP of eroded wind farms slightly lower than AEP of clean farm (baseline and optimised)
- Similar wake losses in all configurations → Slightly smaller as erosion increases
- Static yaw optimisation improves AEP → Gain gets slightly smaller as erosion increases
- Overall, it can be concluded that, for the analysed case, erosion does not have a significant impact in static wake steering WFFC strategies

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[9] https://github.com/OpenFAST/openfast

[10] https://github.com/NREL/floris

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