X-ROTOR

X-shaped Radical Offshore Wind Turbine
for Overall Cost of Energy Reduction

XROTOR disruptive wind turbine advanced aerodynamic analysis using CFD

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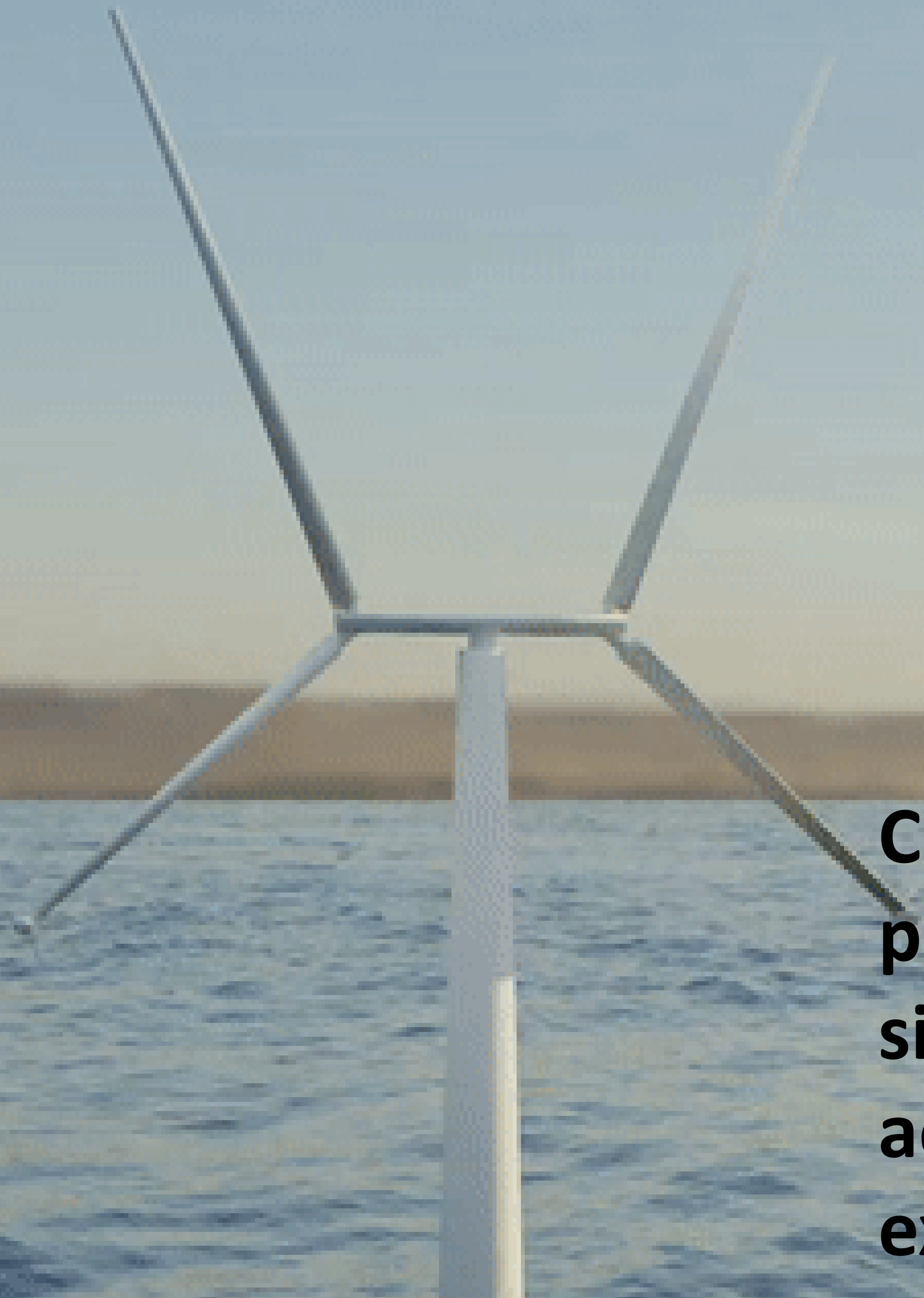
CENER (National Renewable Energy Center- Spain)

EERA DeepWind CONFERENCE 2024

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no. 101007135

CENER

https://xrotor-project.eu



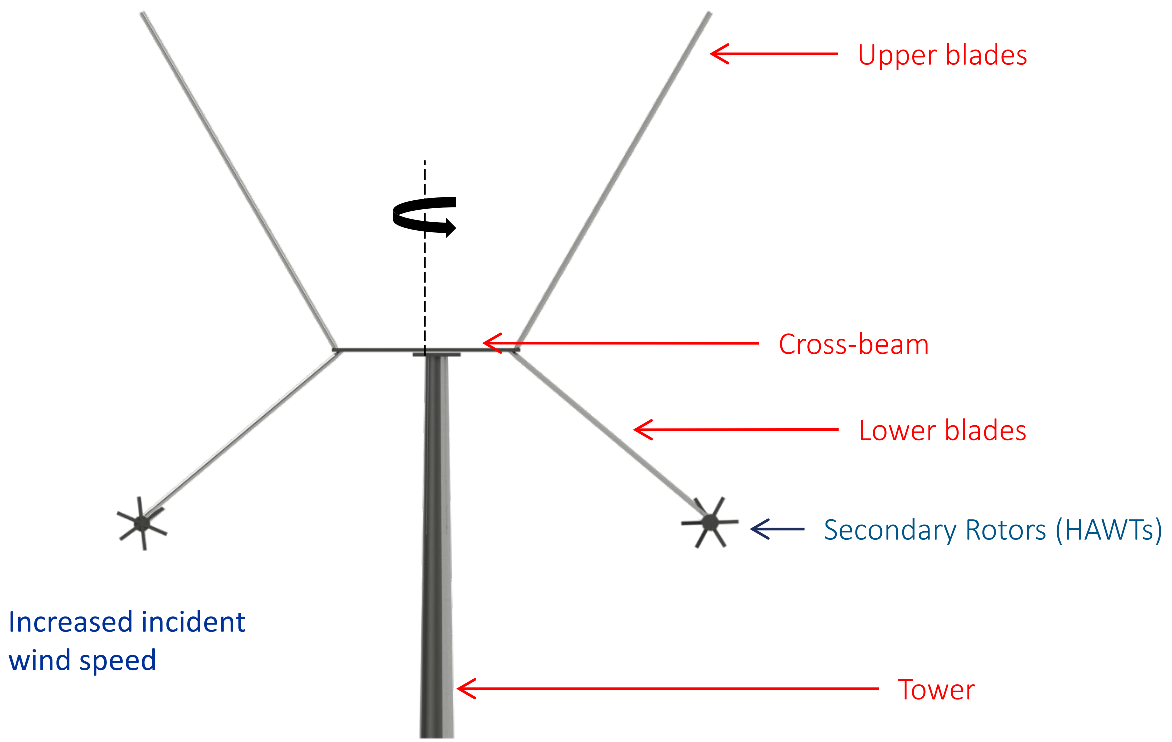
Outline

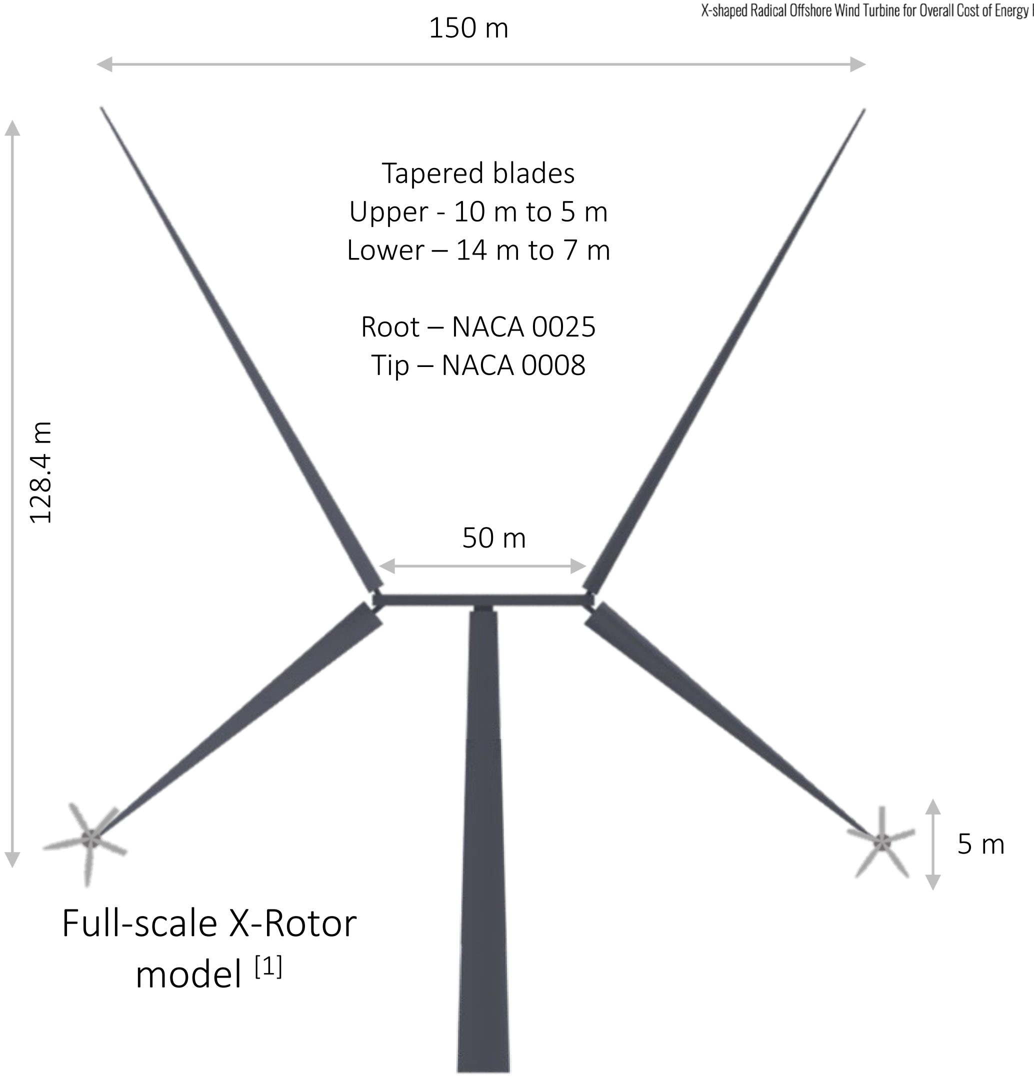
0 Introduction
1 Primary rotor simulations
2 Secondary rotor simulations
3 Full concept simulations
4 Comparisons with Experiments
5 Conclusions

CENER´s role in the Project is to perform XROTOR high fidelity simulations to support aeroelastic code design and experiment.

0 Introduction

Secondary rotors power: 5 MW





Full-scale X-Rotor model [1]

[1] William Leithead, Arthur Camciuc, Abbas Kazemi Amiri, and James Carroll. "The X-Rotor Offshore Wind Turbine Concept". In: Journal of Physics: Conference Series 1356.1 (2019). issn: 17426596. doi: 10.1088/1.

***Images courtesy of TUDelft*

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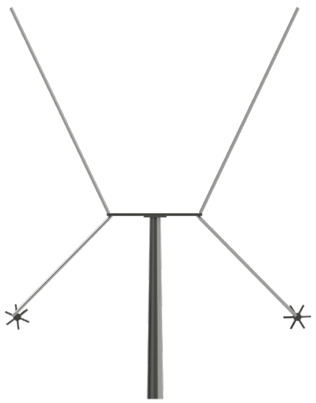
0 Introduction

X-shaped Radical Offshore Wind Turbine for Overall Cost of Energy Reduction

Step by step approach

CFD Analysis approach (OpenFOAM)



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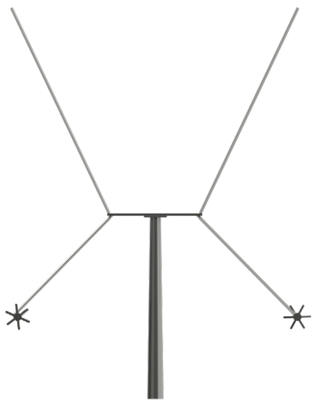

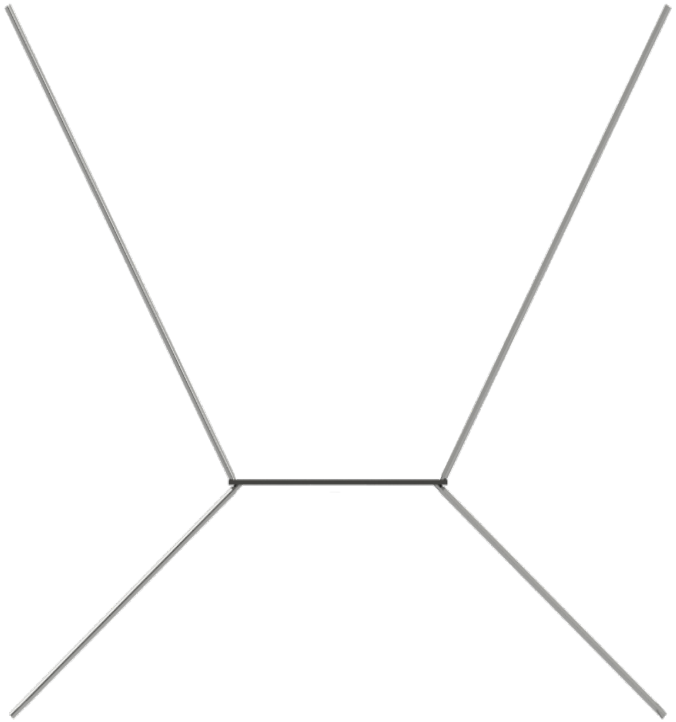

CFD Analysis approach (OpenFOAM)

- *STEP1: Isolated primary rotor simulation*

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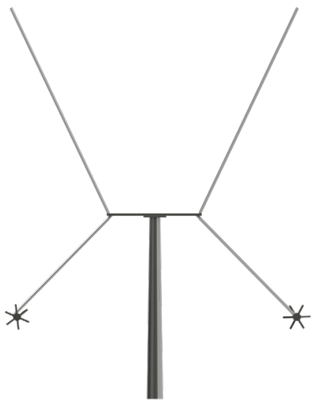

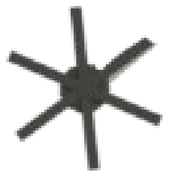

CFD Analysis approach (OpenFOAM)

- *STEP1: Isolated primary rotor simulation*
- *STEP2: Secondary rotor simulation*

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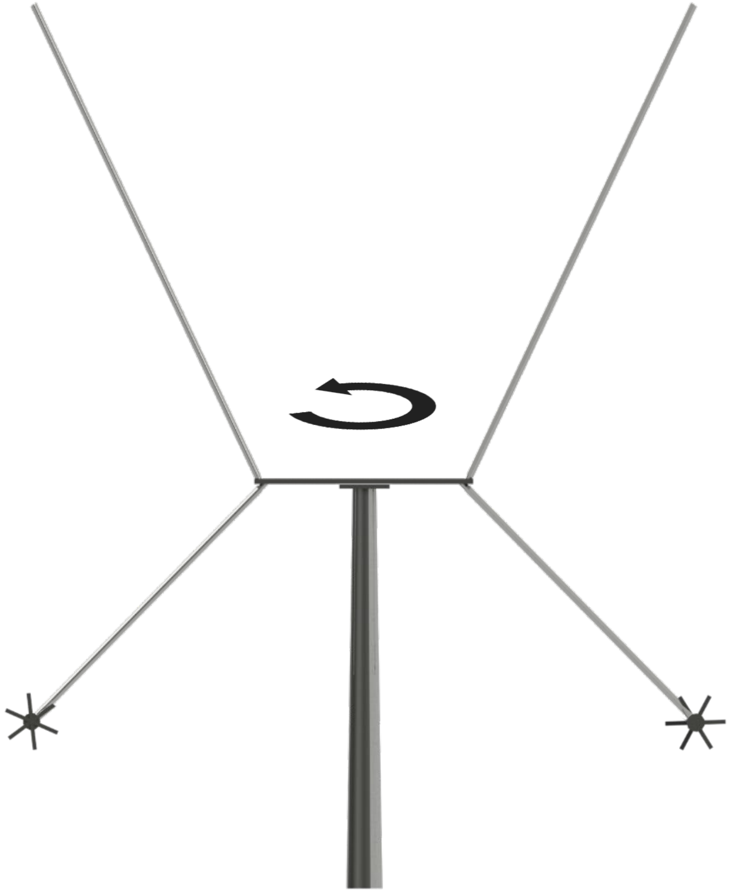

CFD Analysis approach (OpenFOAM)

- *STEP1: Isolated primary rotor simulation*
- *STEP2: Secondary rotor simulation*
- ***STEP3: Full concept simulation***

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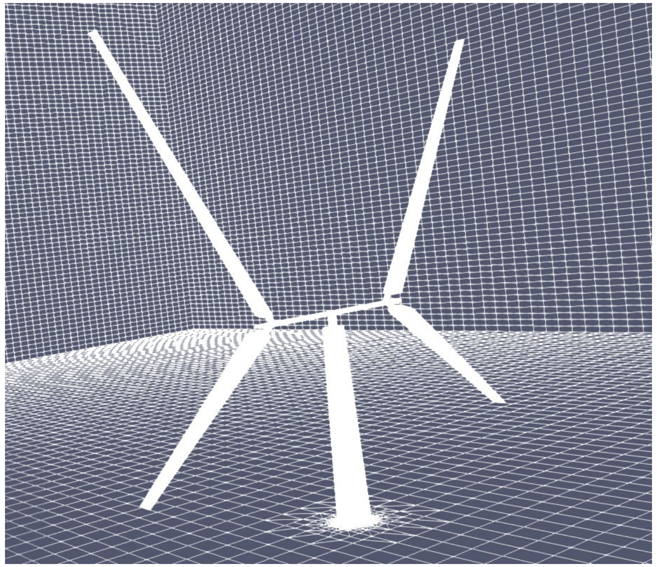
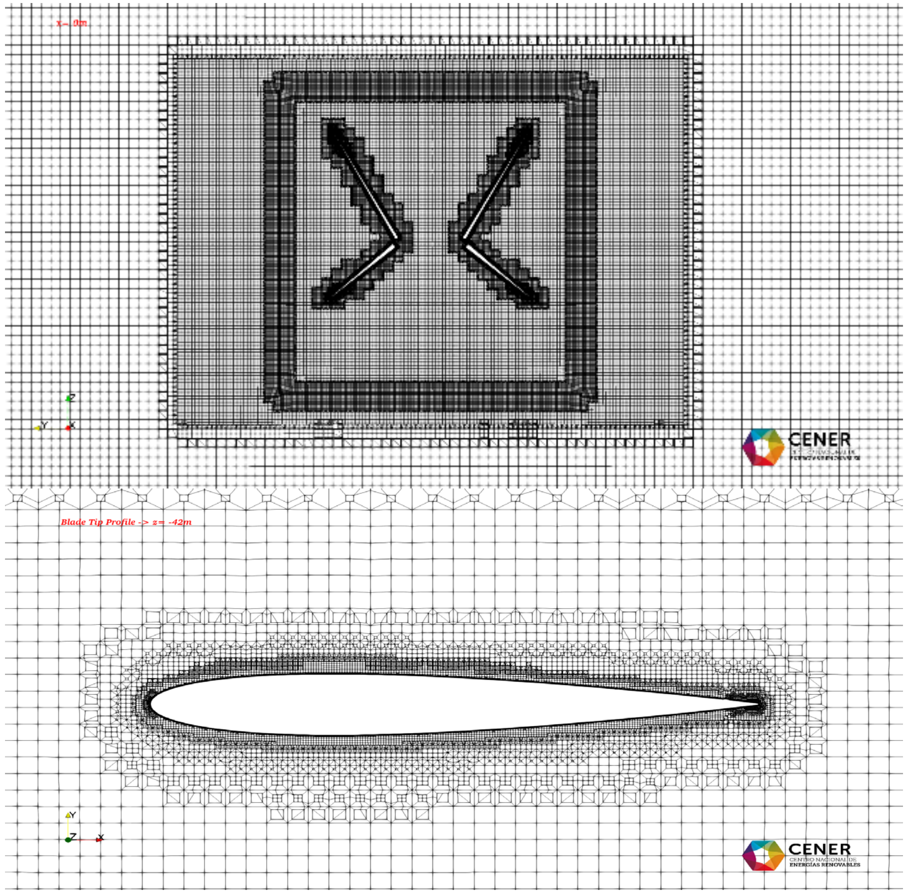
STEP1 Primary Rotor Simulations

X-shaped Radical Offshore Wind Turbine for Overall Cost of Energy Reduction

Simulation characteristics

- Openfoam v8
- SnappyHexMesh used to create the meshes
- Sliding meshes to communicate the rotating parts to the static parts
- Wake and airfoil refinements crucial: 73 million cells





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STEP1 Primary Rotor Simulations

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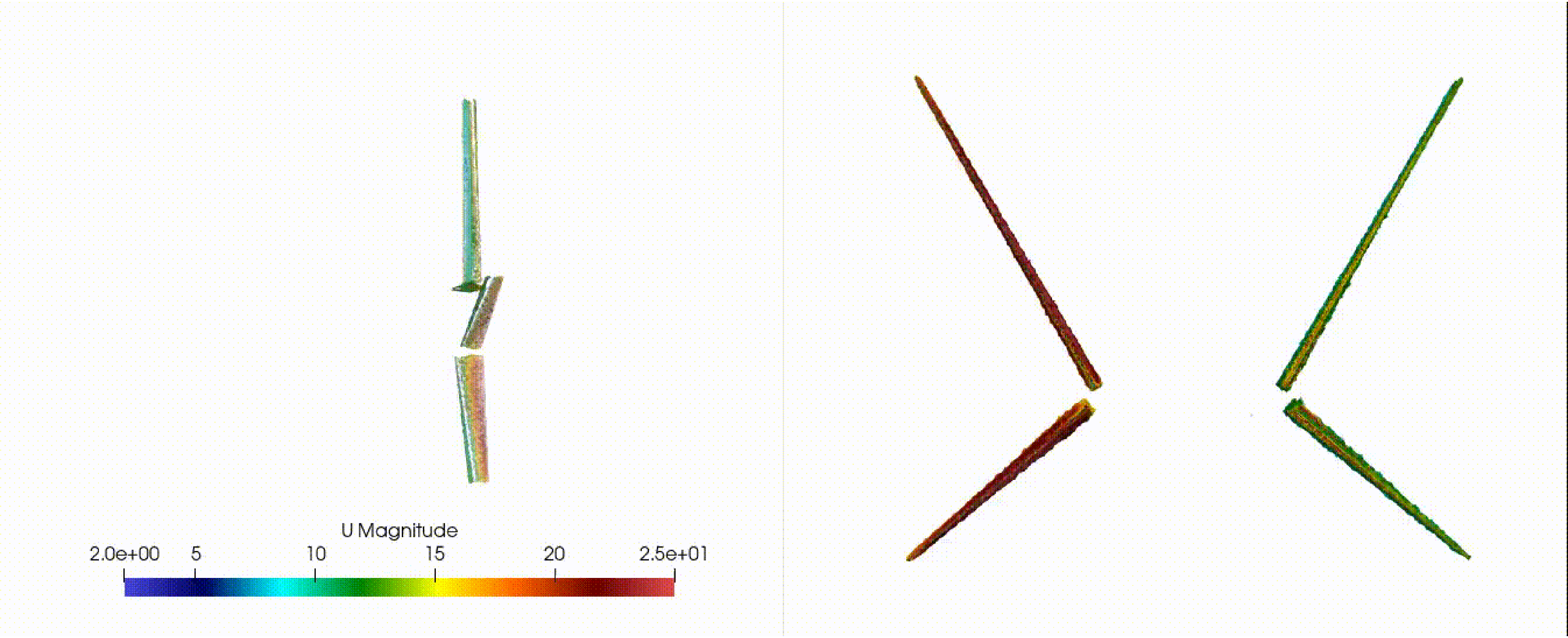

Nominal power case (v=12.5 m/s, Ω=0.838 rad/s, pitch 0º)

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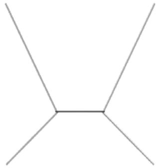
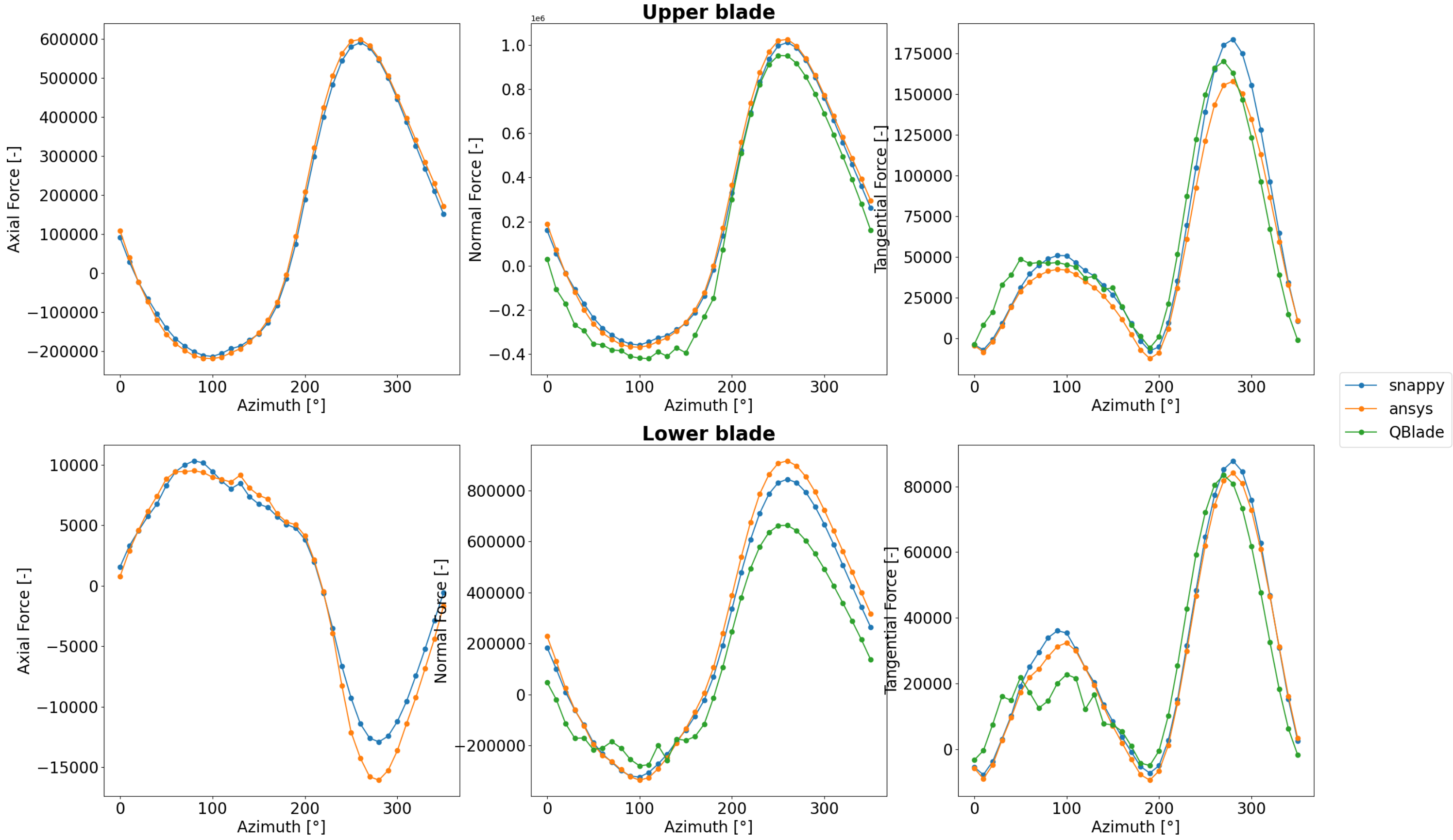
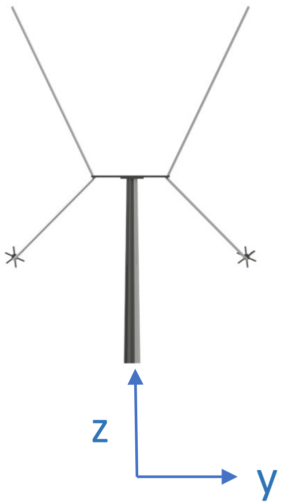
STEP1 Primary Rotor Simulations





Forces plotted in Blade Axis

Aero benchmark publication: (under review): *Giri Ajay, A., Morgan, L., Wu, Y., Bretos, D., Cascales, A., Pires, O., and Ferreira, C.: Aerodynamic model comparison for an X-shaped vertical-axis wind turbine, Wind Energ. Sci. Discuss. [preprint], https://doi.org/10.5194/wes-2023-115, in review, 2023*



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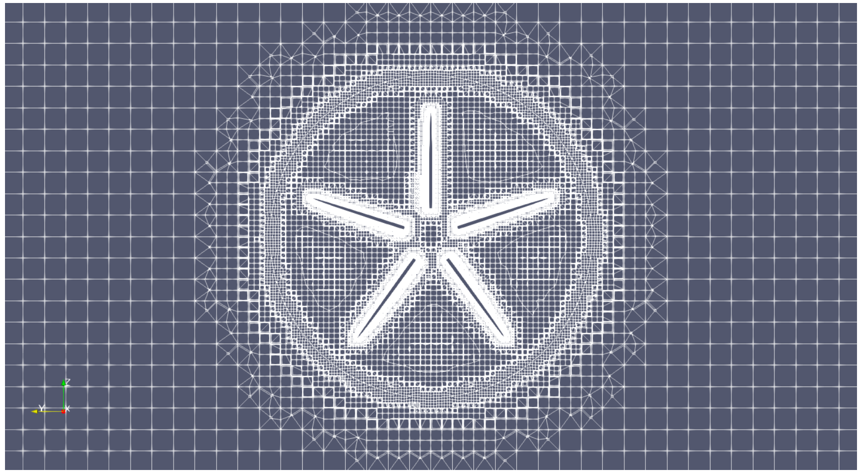
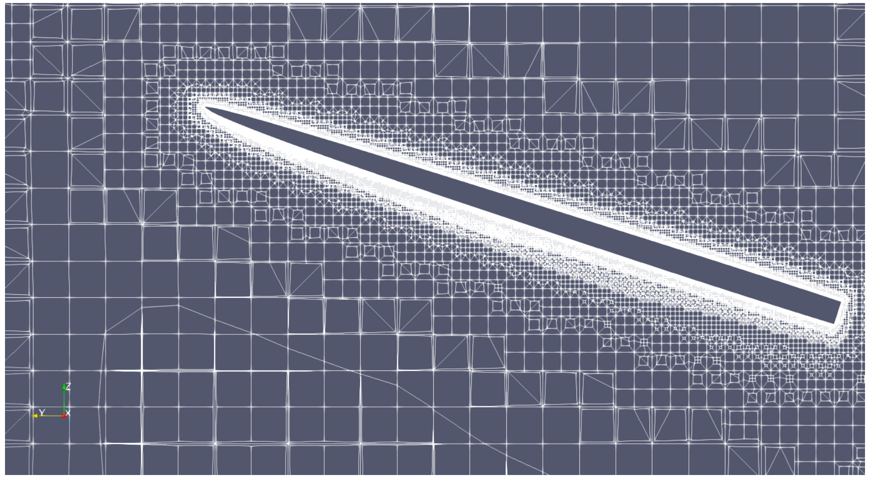
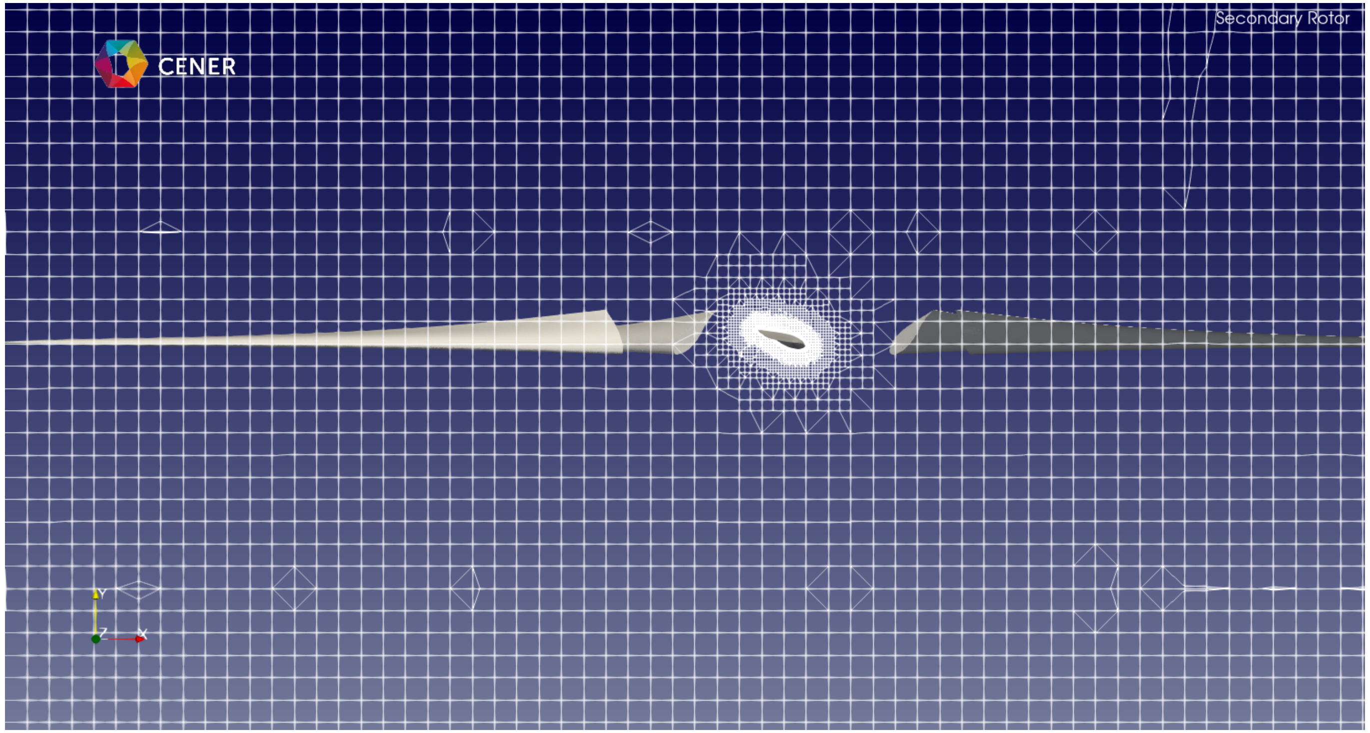
STEP2 Secondary Rotor Simulations

- Openfoam v8 and SnnapyHexMesh
- Sliding Mesh
- 39 million cells, minimum distance to the wall 1.5e-4







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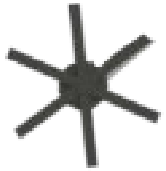
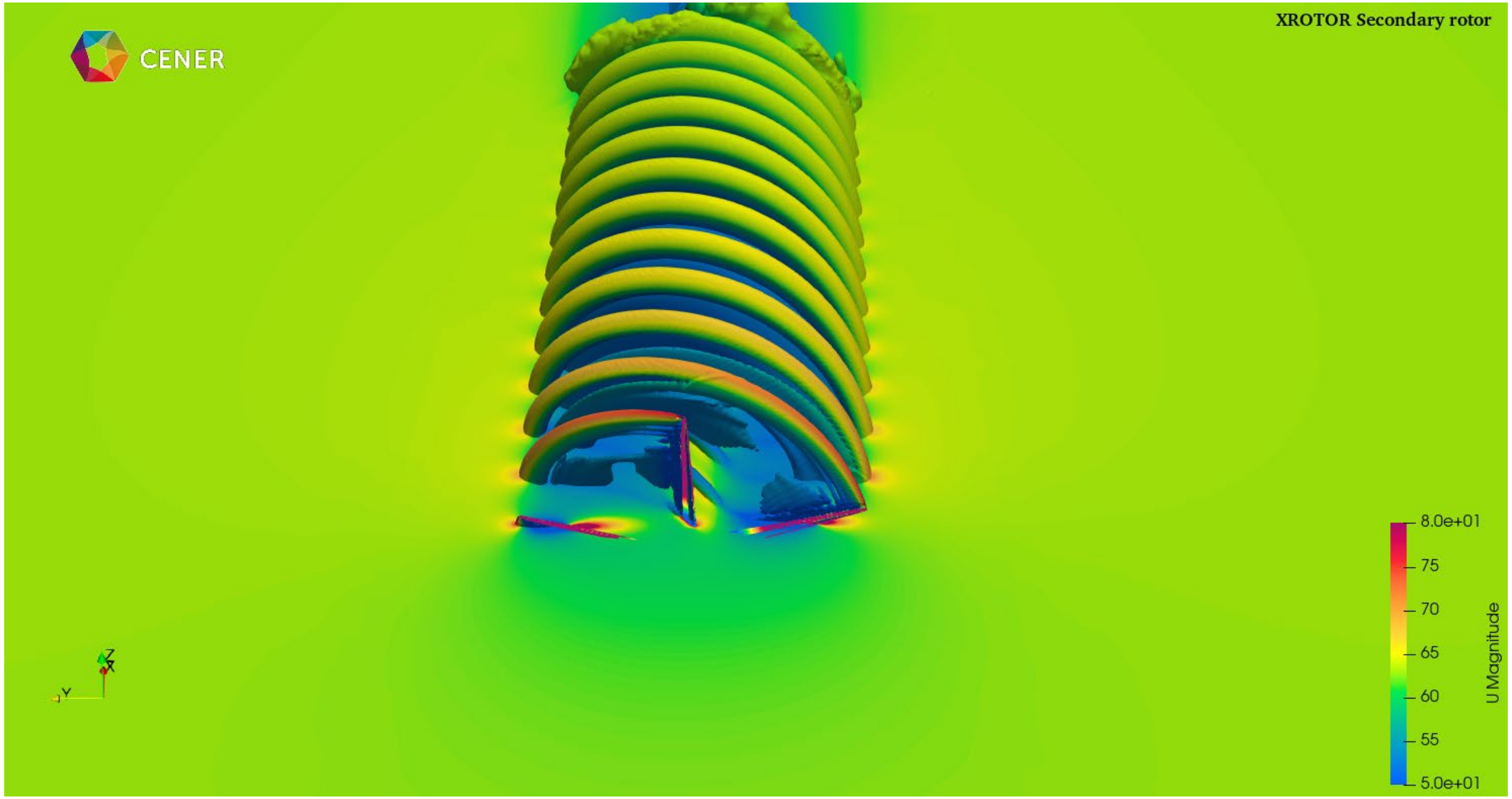
STEP2 Secondary Rotor Simulations





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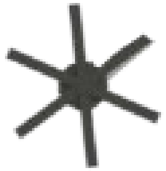
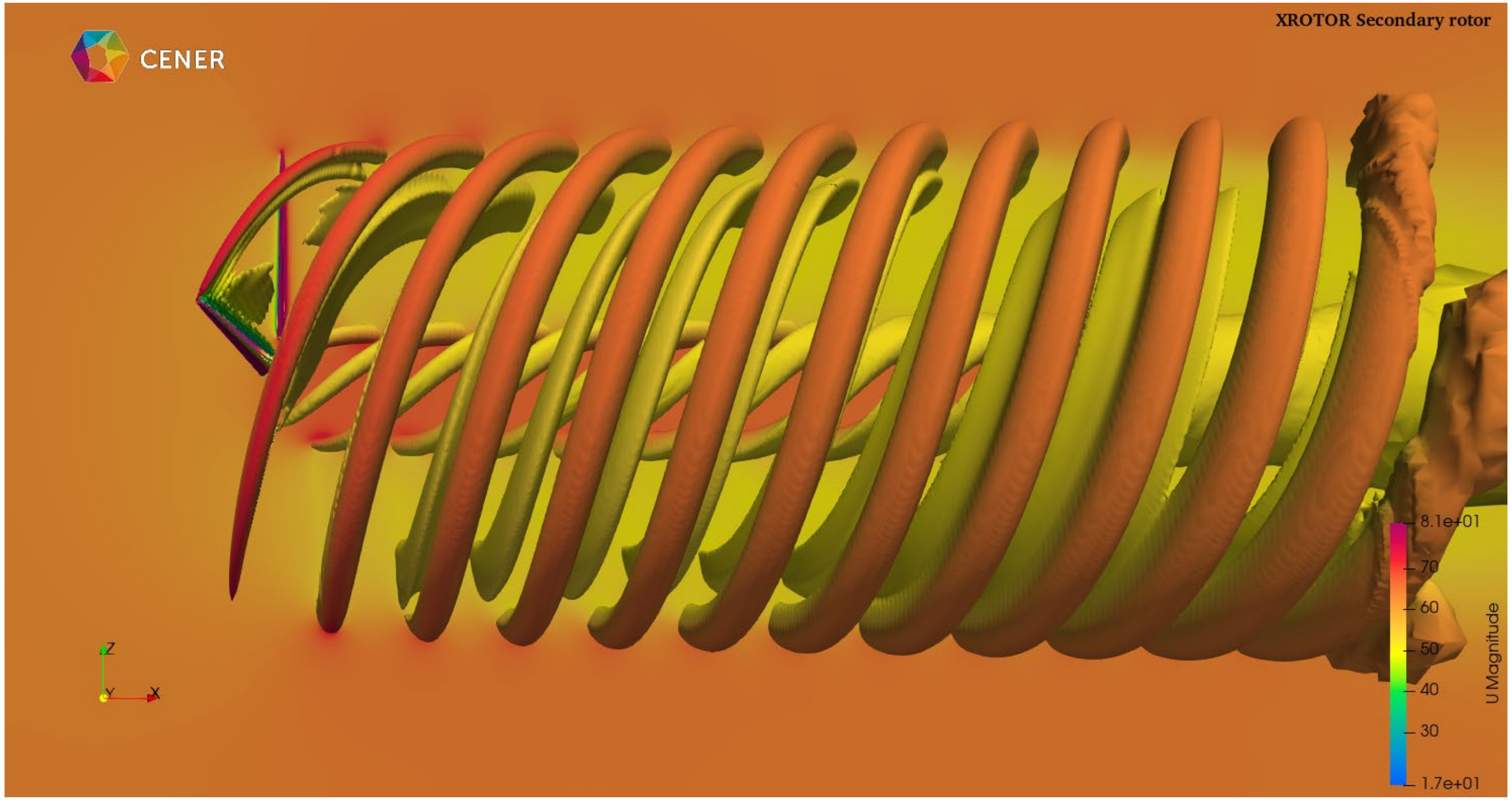
STEP2 Secondary Rotor Simulations





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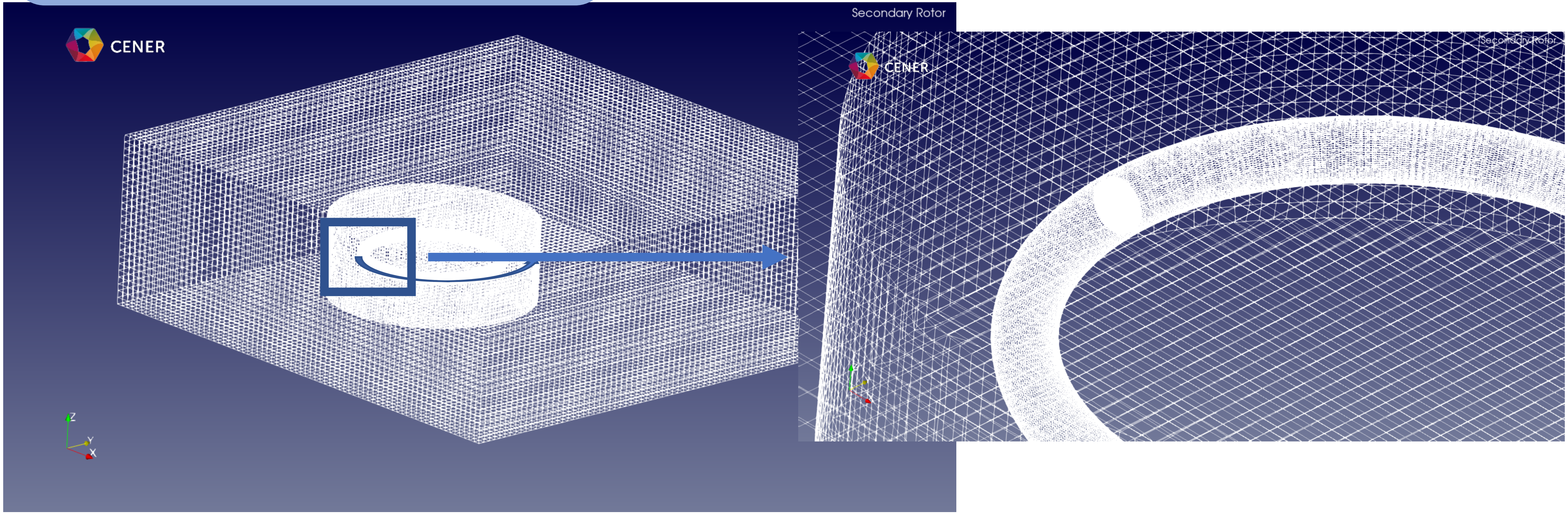
STEP2 Secondary Rotor Simulations

- Second rotation included without the primary rotor
- Openfoam & SnappyHexMesh
- Transient simulation



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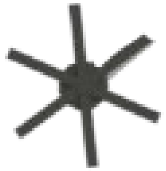
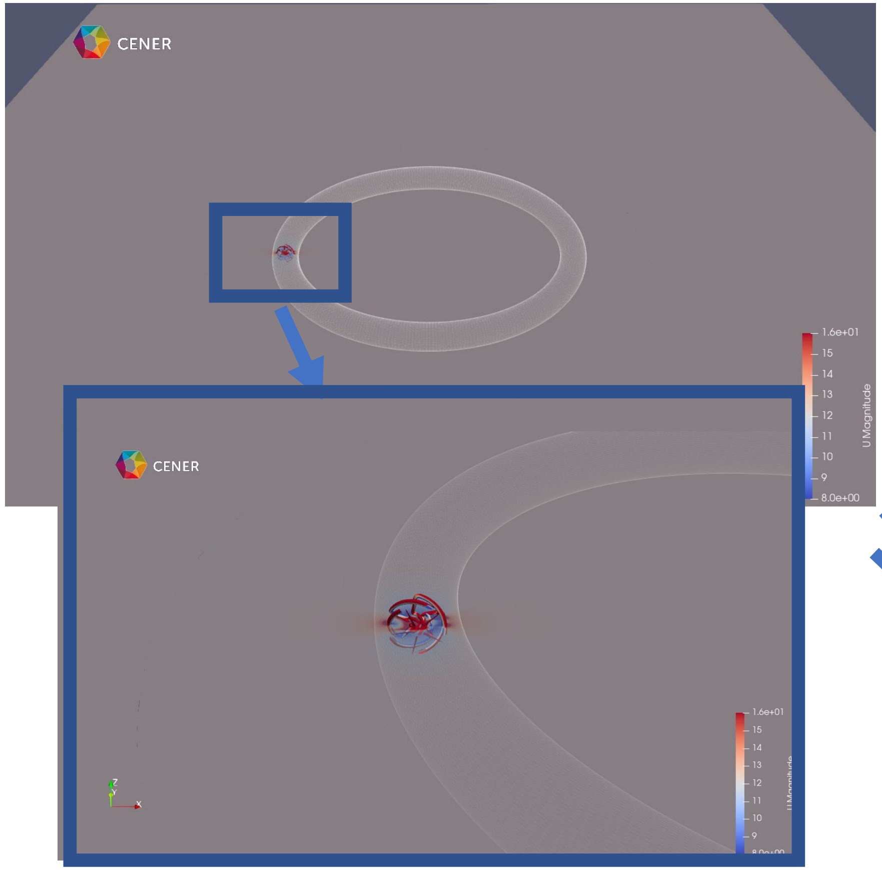
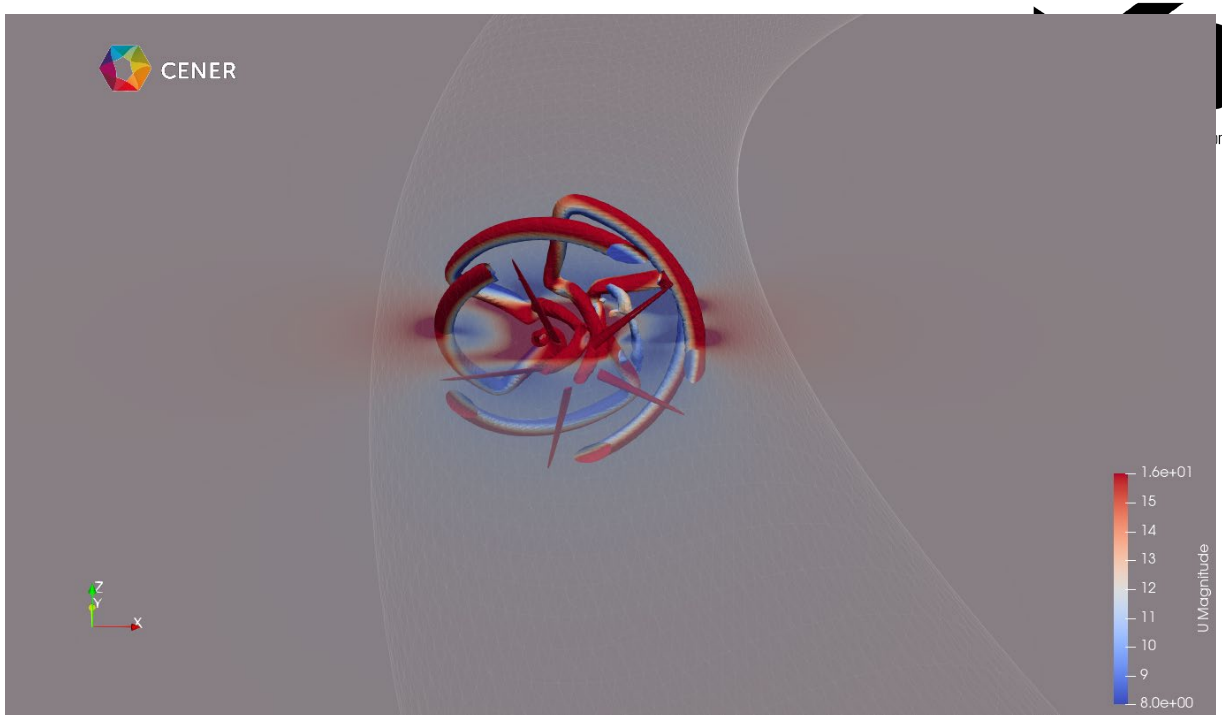
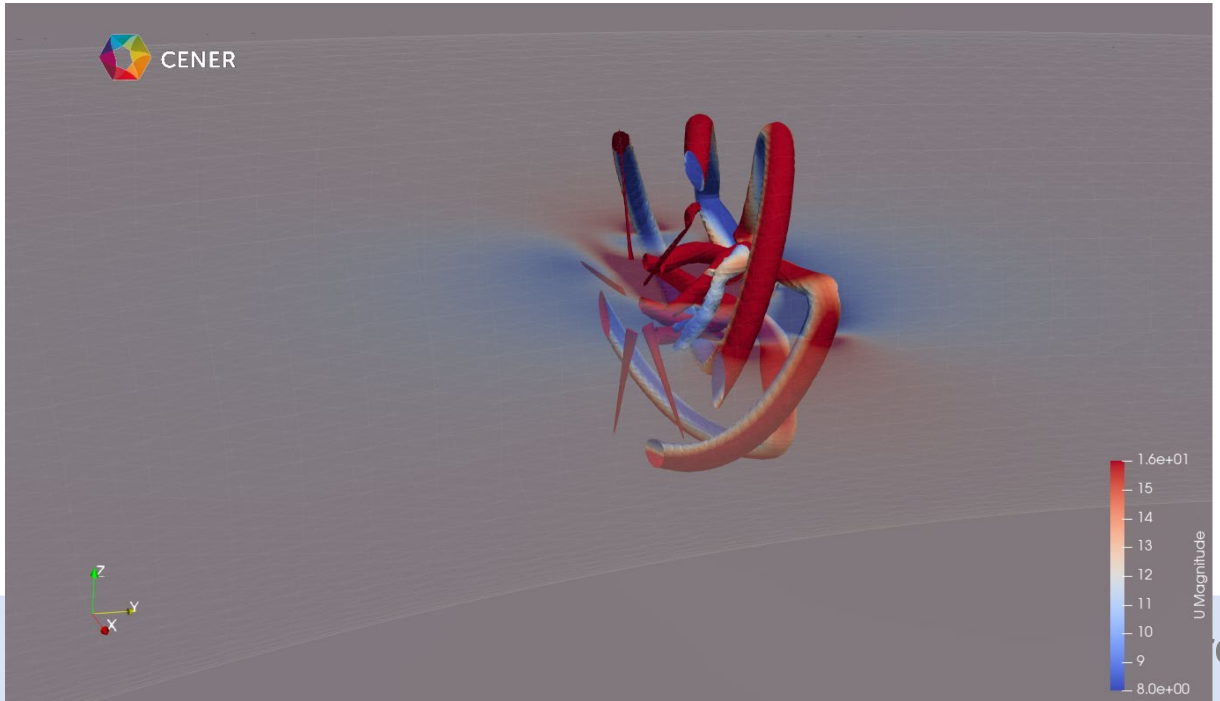
STEP2 Secondary Rotor Simulations



r Overall Cost of Energy Reduction







Complex wake due to the combined rotations.

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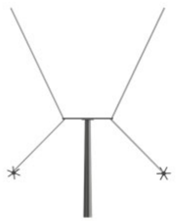
STEP3 Full Rotor Simulations



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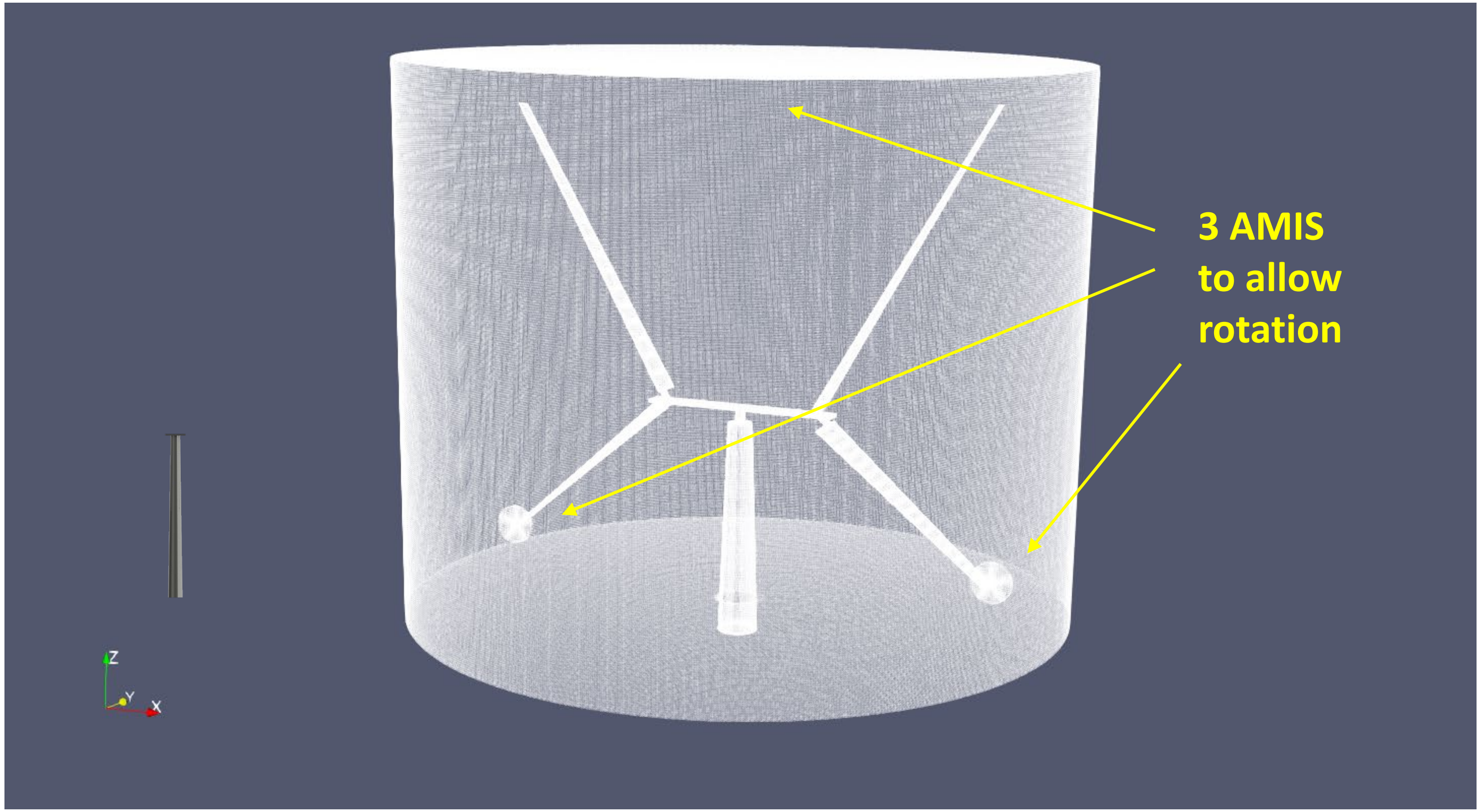

- Dynamic mesh computation
- Multi-motion simulation rotating interfaces
- 2 rotational axis

<u>Complex wake interactions:</u>

- Primary blades wake
- Secondary rotors wake
- Tower wake

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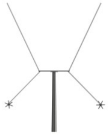
STEP3 Full Rotor Simulations



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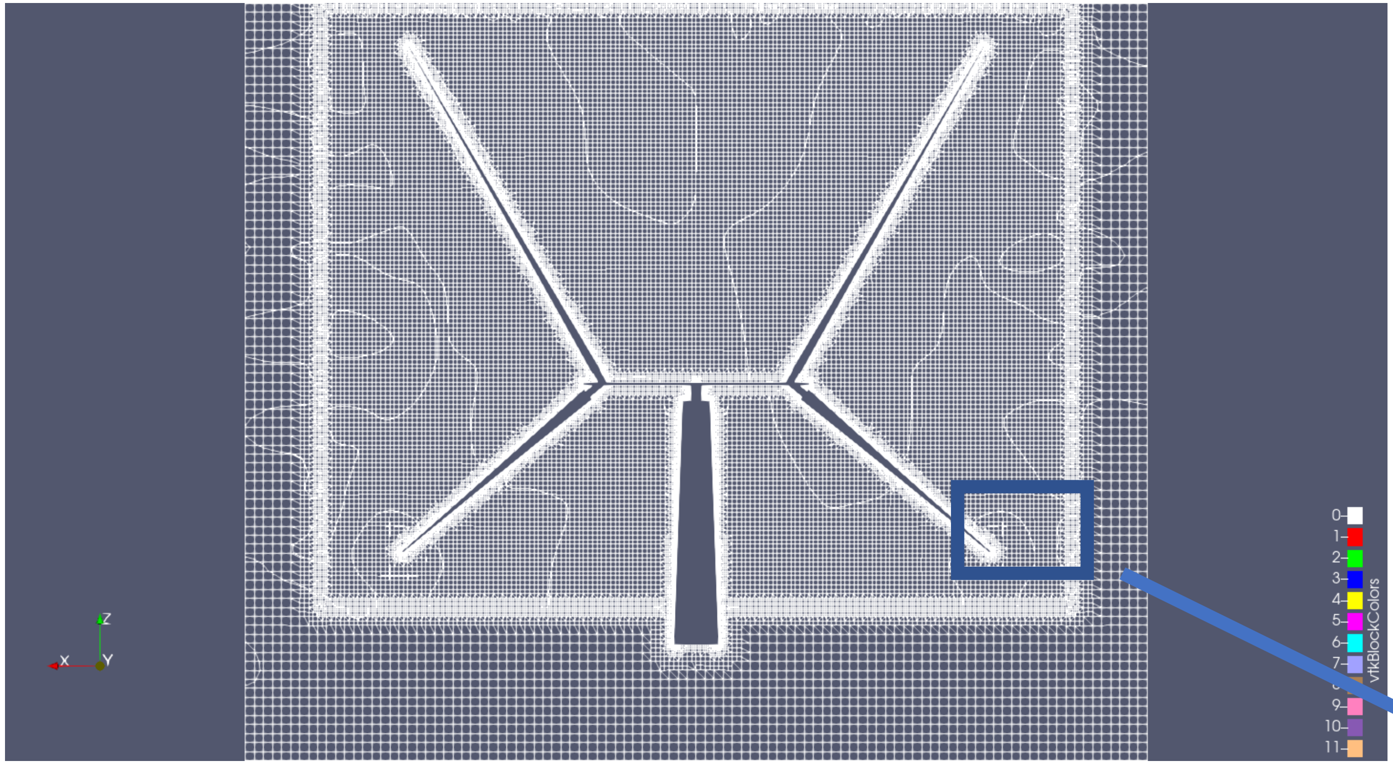
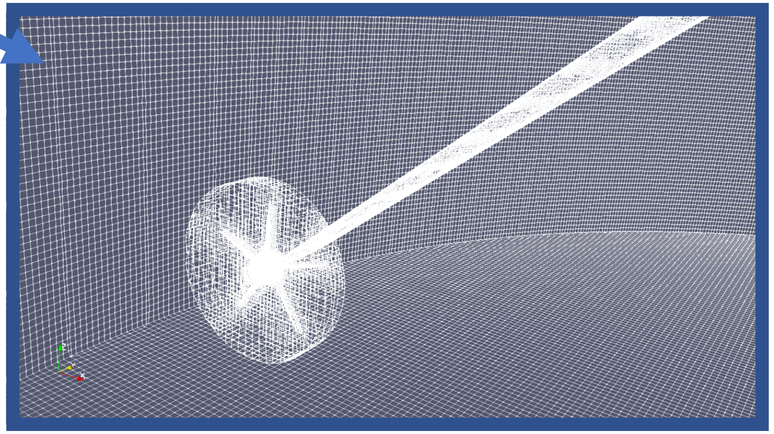


Mesh characteristics

- 120 Million cells.
- Different boundary layer scales in the primary and secondary blades surfaces.



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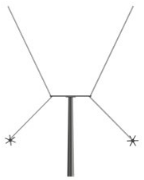
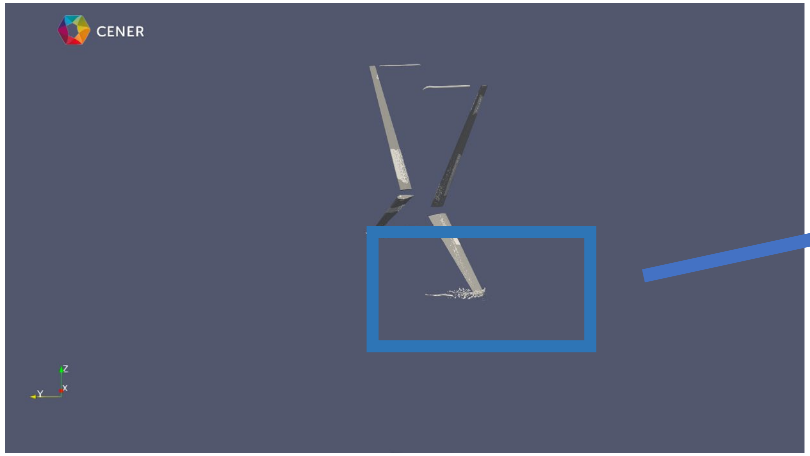
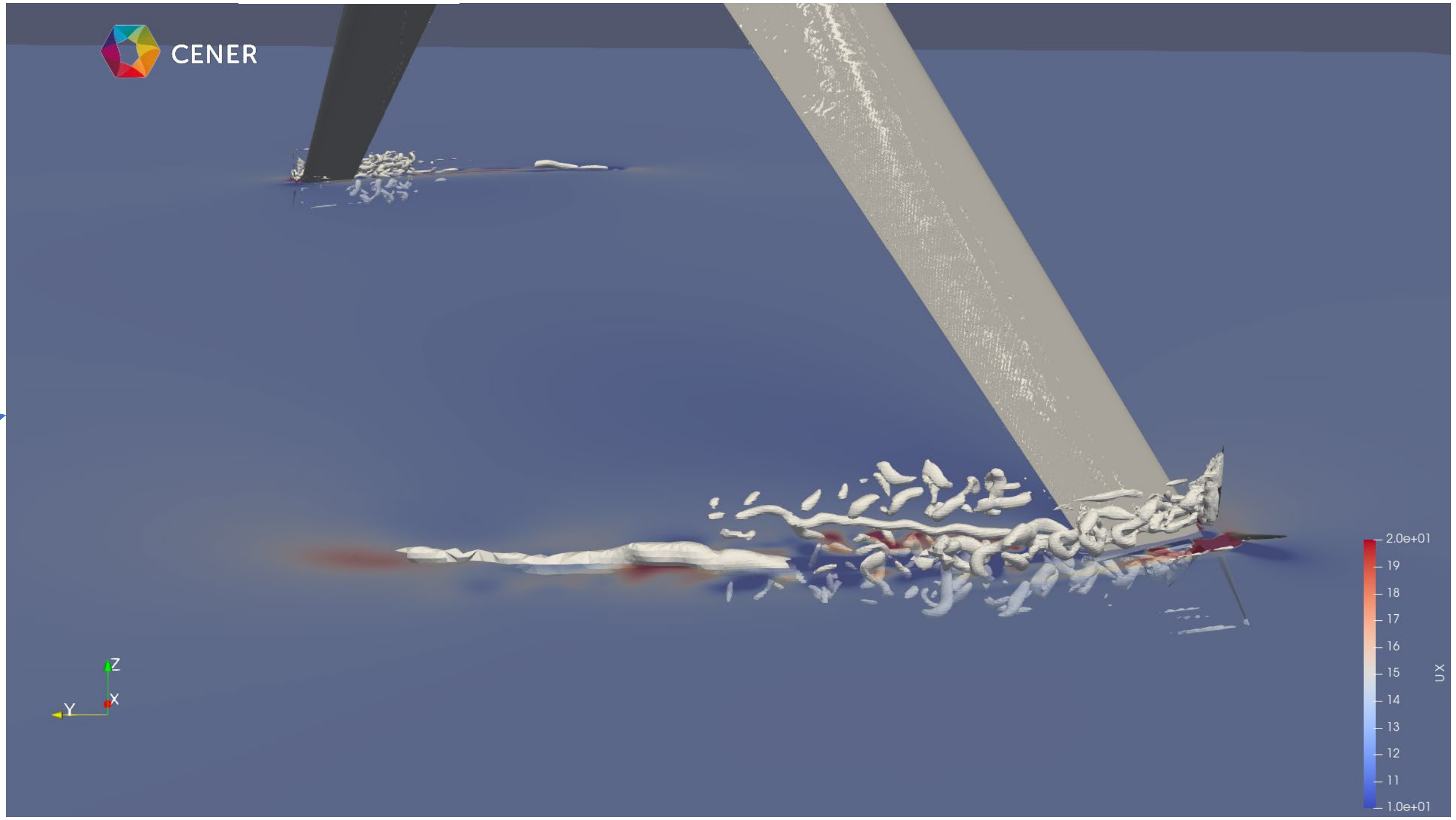
STEP3 Full Rotor Simulations







3.8 rotations of the secondary rotor

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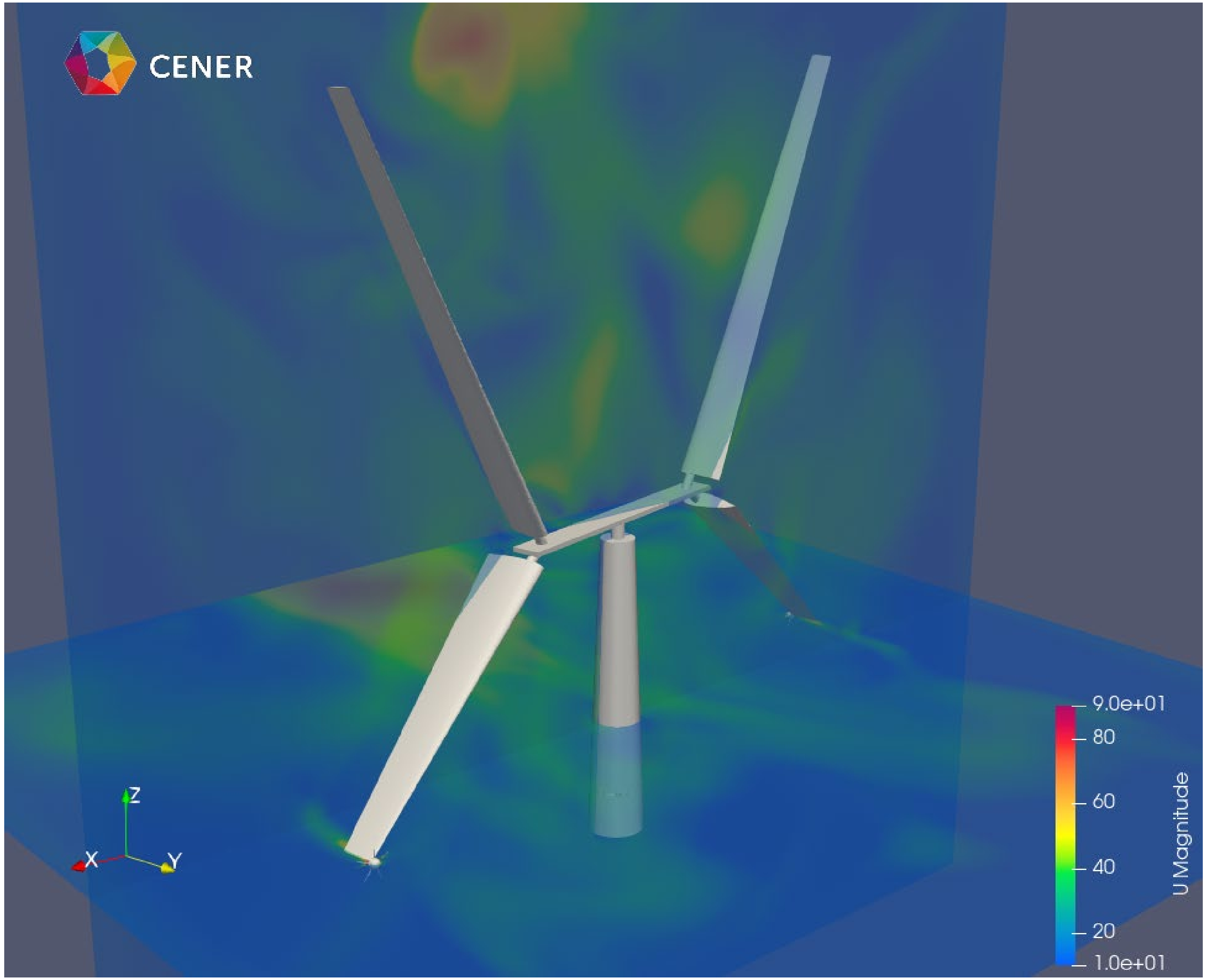
STEP3 Full Rotor Simulations



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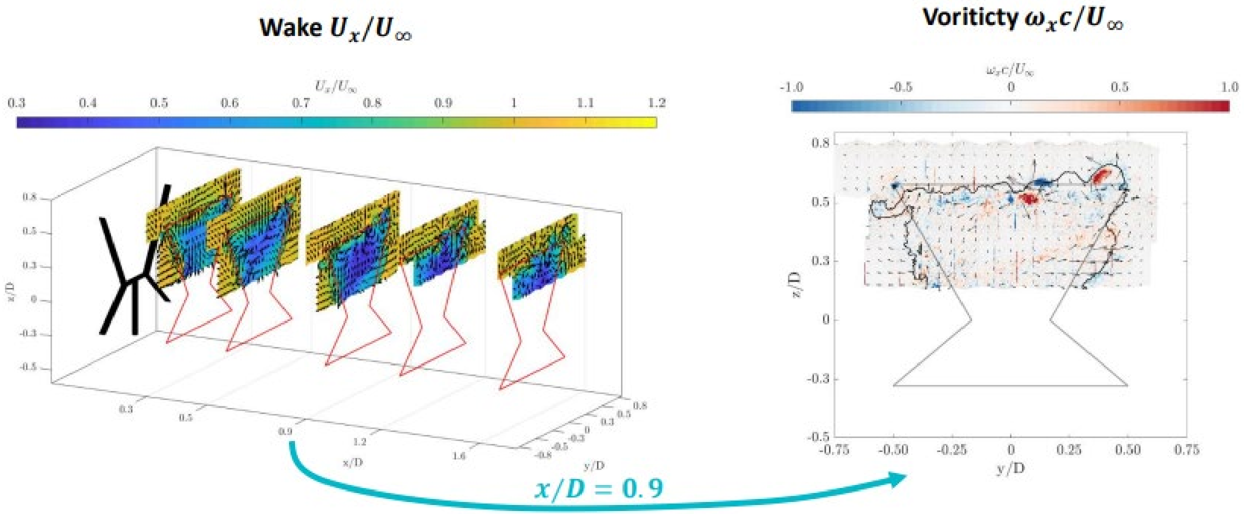
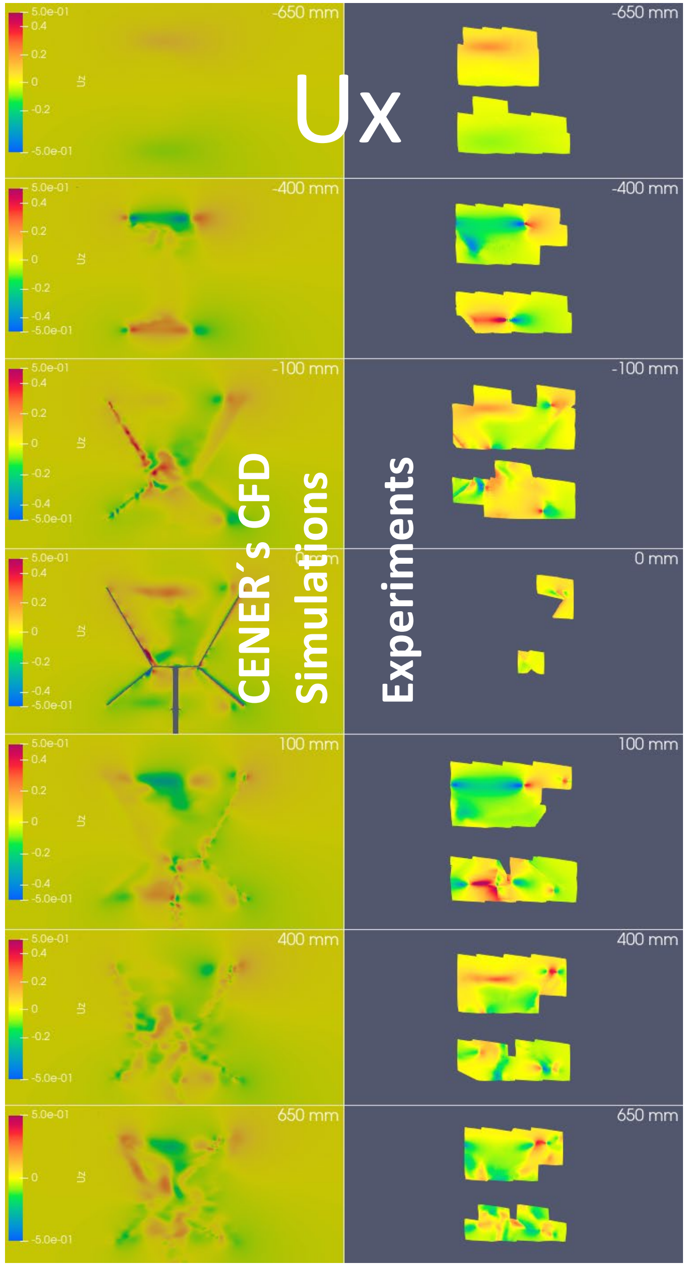
4 Comparison with the experimental campaign performed by TUDelft.



Experiments performed at TU Delft: David Bensason et al 2023 J. Phys.: Conf. Ser. ***2505*** *012040****DOI*** *10.1088/1742-6596/2505/1/01204*



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4 Comparison with experiments.

XROTOR
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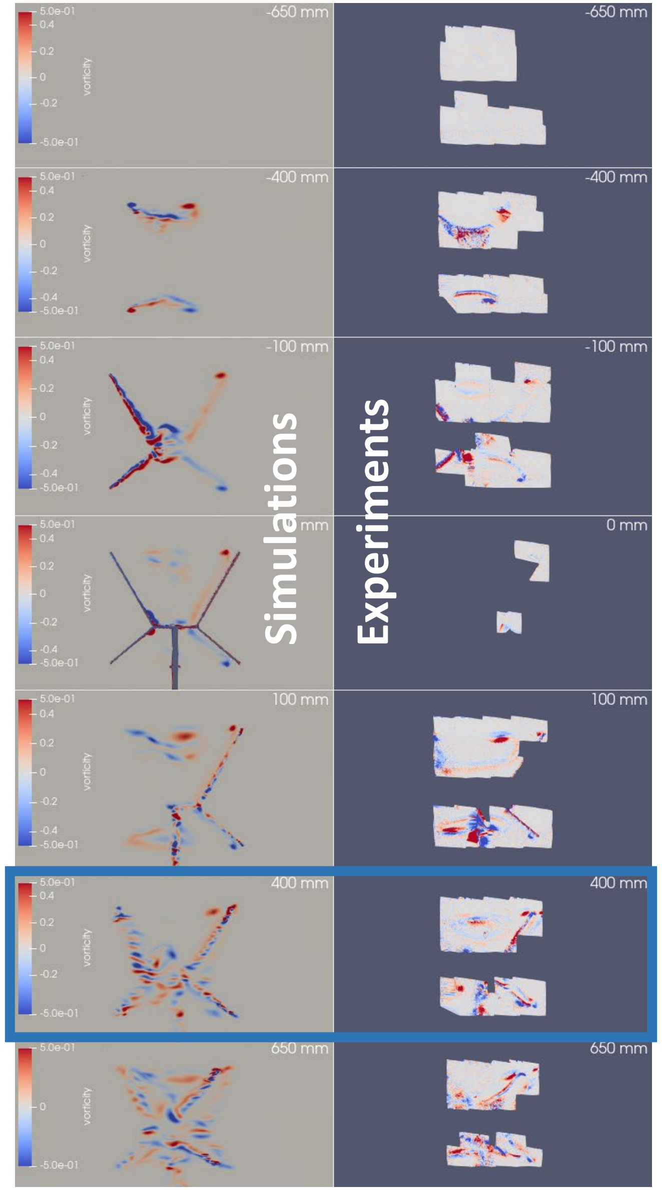
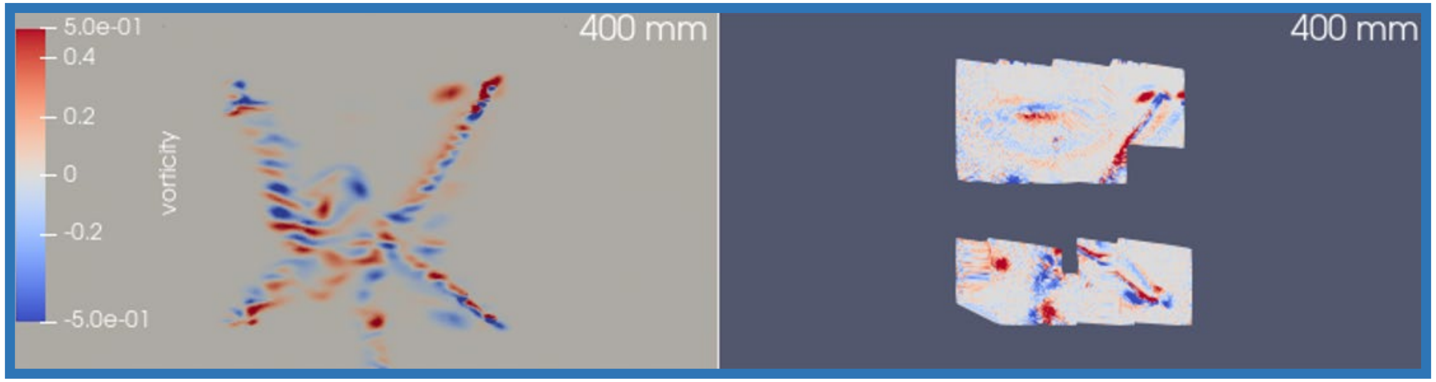
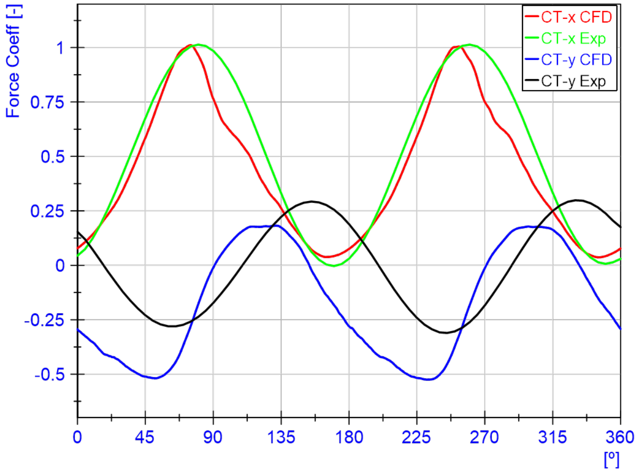
VorticityX







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5 Conclusions

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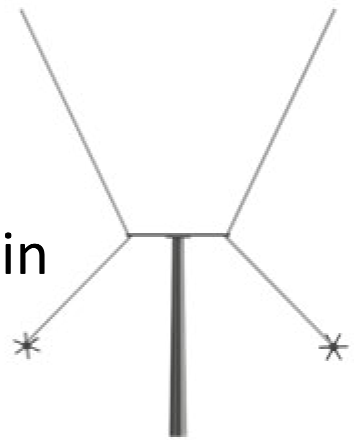
- Flexibility and versatility of the CFD tool
- Successful Step by step approach
- Strong know-how achieved
- CFD can provide outputs that other tools or experiments cannot obtain



- Several flow scales including strong wake interactions simulated
- Wake and blades refinement is necessary to match the ACTUAL power production and model the complex flow phenomena
- Compressibility effects in the secondary rotors should be included

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Thank you!

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