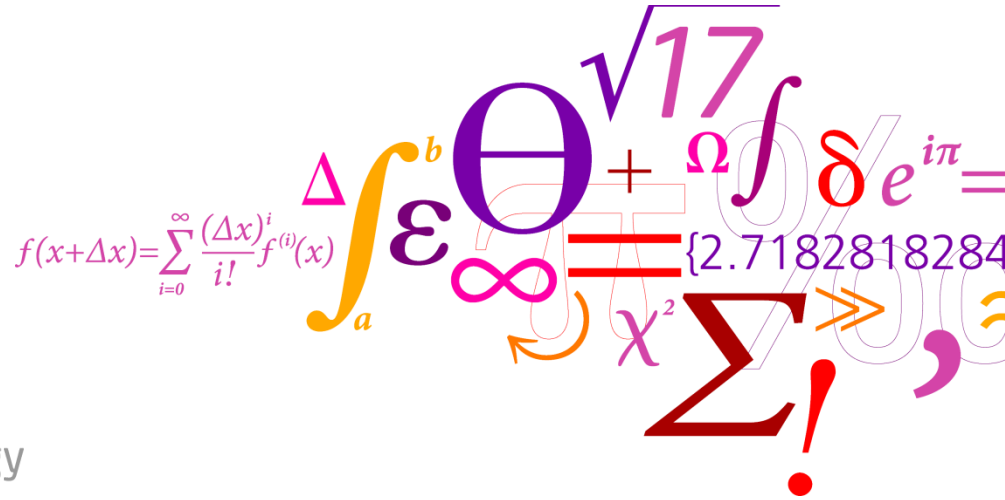
Coupling the Navier Stokes actuator line model with the aeroelastic solver HAWC2

Niels Troldborg and Joachim Heinz

Wind Energy Department, DTU Wind Energy, DK-4000 Roskilde, Denmark



Risø DTU
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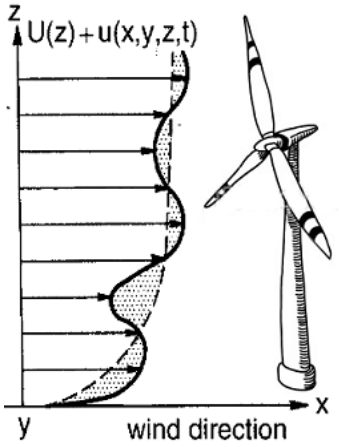
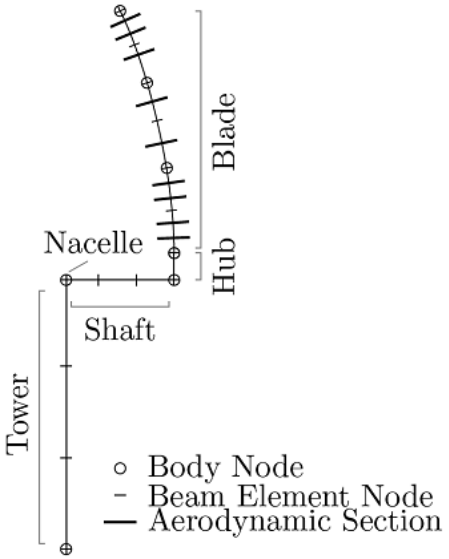
HAWC2

Predicts structural response of wind turbine in time domain

- Structural model:
  - Multibody formulation (multiple degrees of freedom)
  - Large deflections, torsion, etc.

- Aerodynamic model:
  - Blade Element Momentum (BEM) theory with sub models (corrections):
    - Dynamic stall
    - Skew inflow
    - Dynamic inflow
    - Wake
    - .....





Rotor CFD using EllipSys3D

Simulates the flow field around the wind turbine

- Flow model:
  - Finite volume discretized Navier-Stokes equations (RANS or LES)
  - Detailed modelling of flow around the rotor
- Rotor models:
  - Fully resolved (FR), actuator line (AL) or actuator disk (AD)
    - Stiff rotor, no control

FR

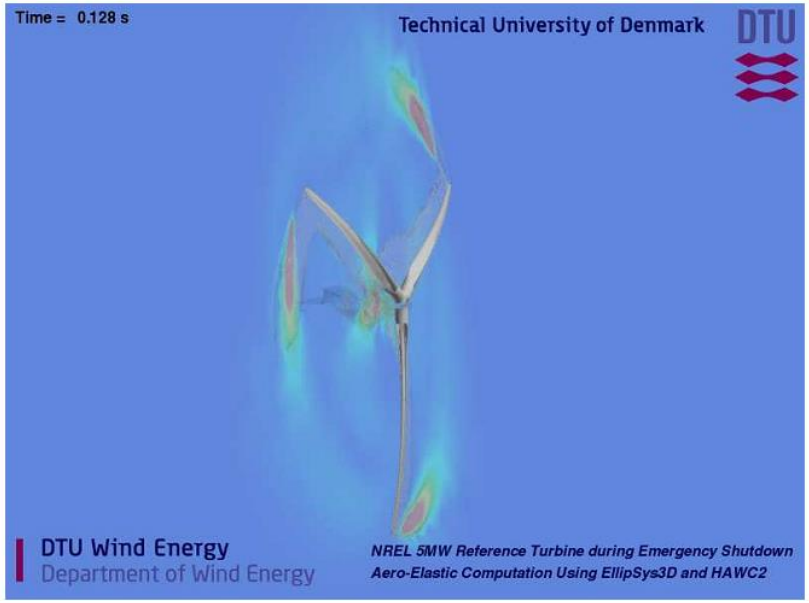
AL

AD

Coupling of HAWC2 with fully resolved rotor CFD

Aero-elastic rotor CFD (by JHEI):

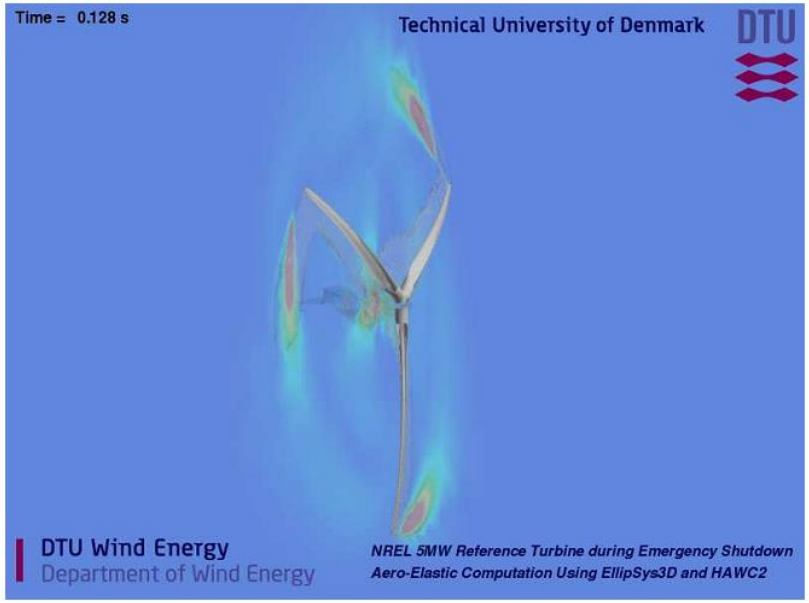
- Structural response computed with HAWC2
- Aerodynamic forces computed with EllipSys3D
  - Fully meshed rotor
  - Blade deformation captured using deforming meshes

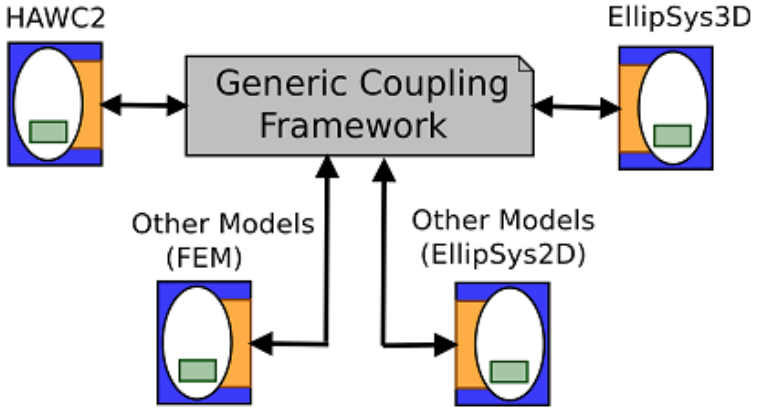


Coupling of HAWC2 with fully resolved rotor CFD

Aero-elastic rotor CFD (by JHEI):

- Structural response computed with HAWC2
- Aerodynamic forces computed with EllipSys3D
  - Fully meshed rotor
  - Blade deformation captured using deforming meshes
- Coupled using OpenMDAO framework
  - Execution and connection of different codes and optimizers
  - Open source (written in Python)
  - Minimally intrusive
  - Generic (standardized interface functions)
  - Flexible (codes in different languages and on different platforms)

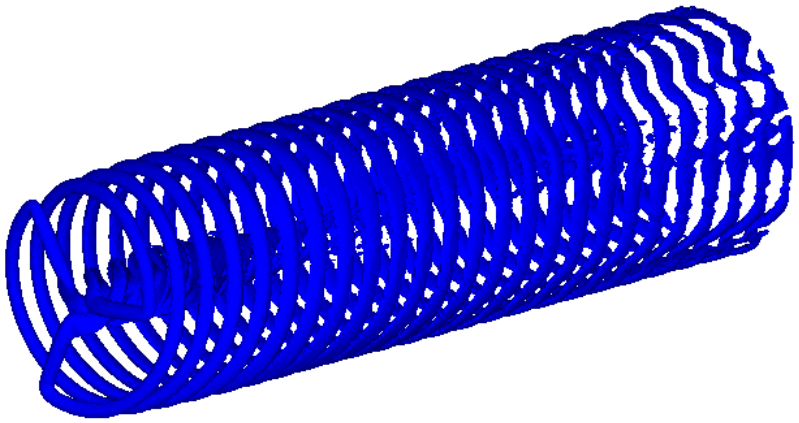




Coupling of HAWC2 and the actuator line model

Objectives and motivation:

- Connect HAWC2 and AL through the OpenMDAO framework
- Flexible AL including control
- Faster than coupling HAWC2 to fully resolved rotor CFD



Coupling of HAWC2 and the actuator line model

- Coupling of HAWC2 and AL is relatively simple
  - Both based on blade element theory and airfoil data

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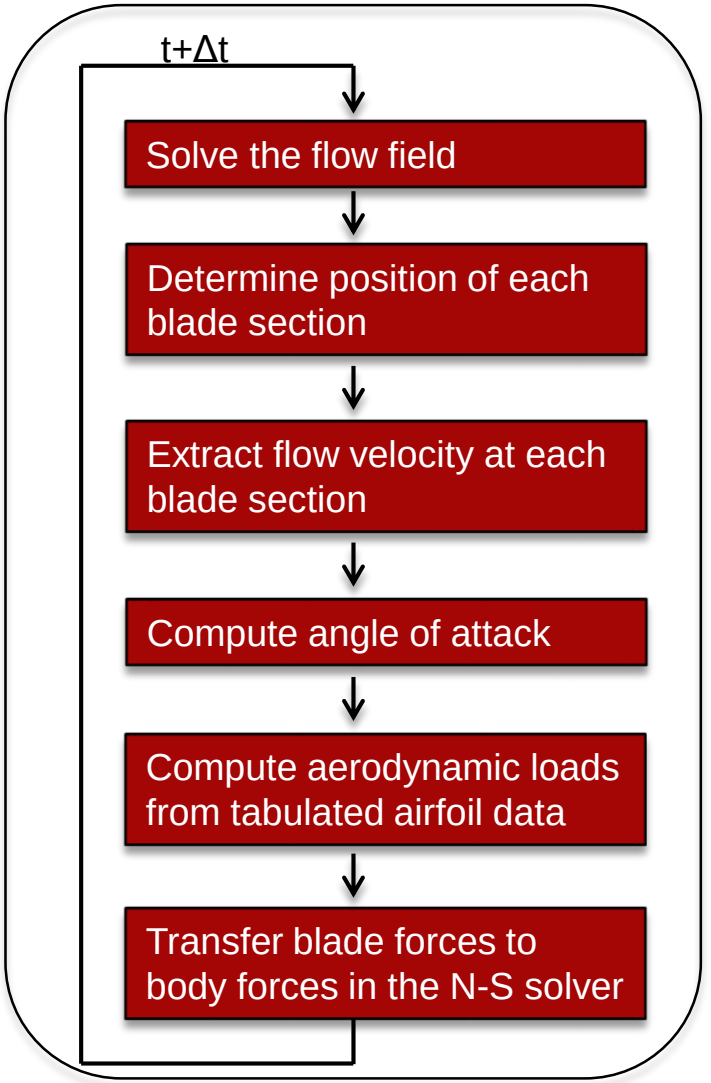
Original AL in EllipSys3D



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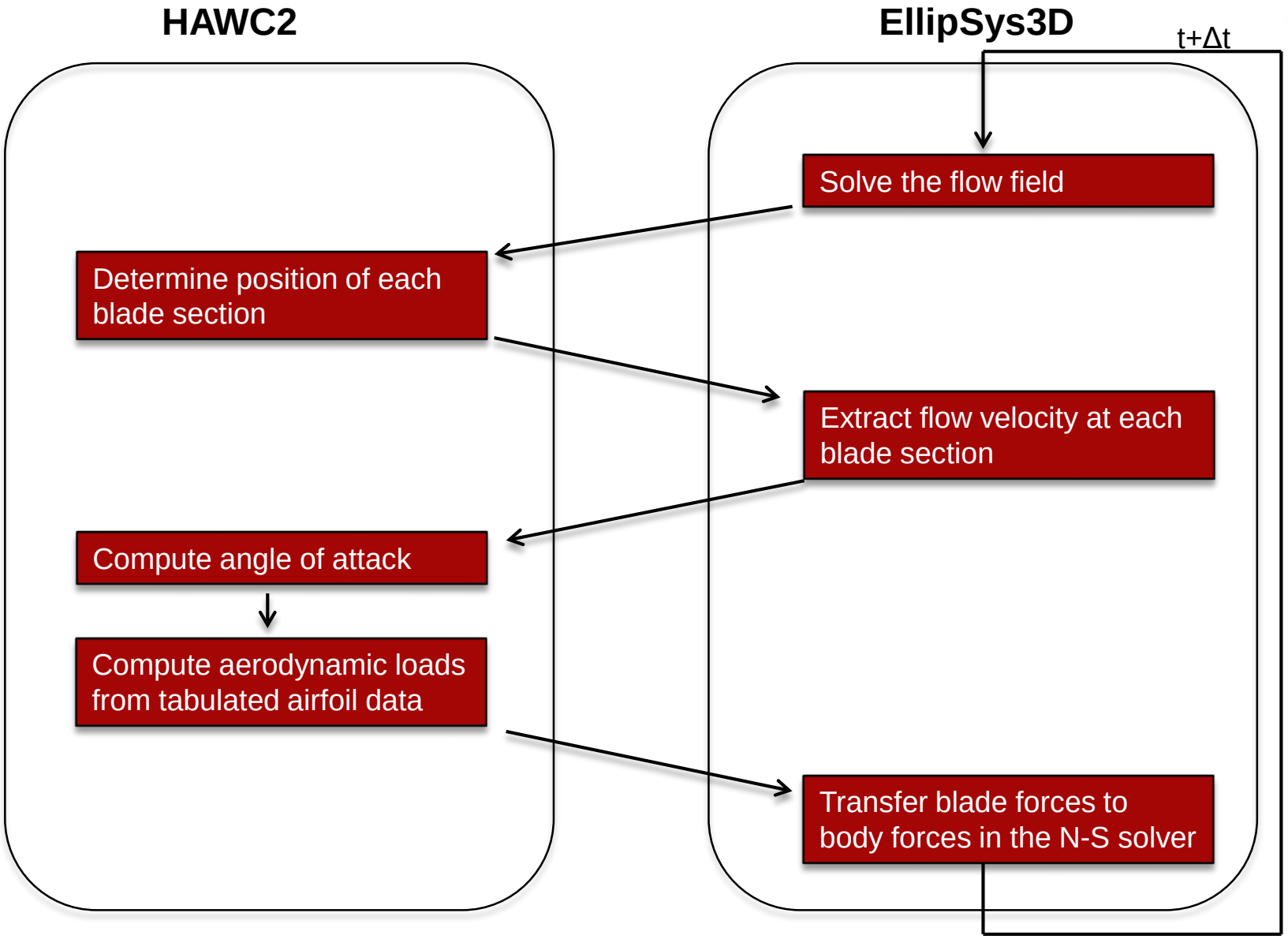

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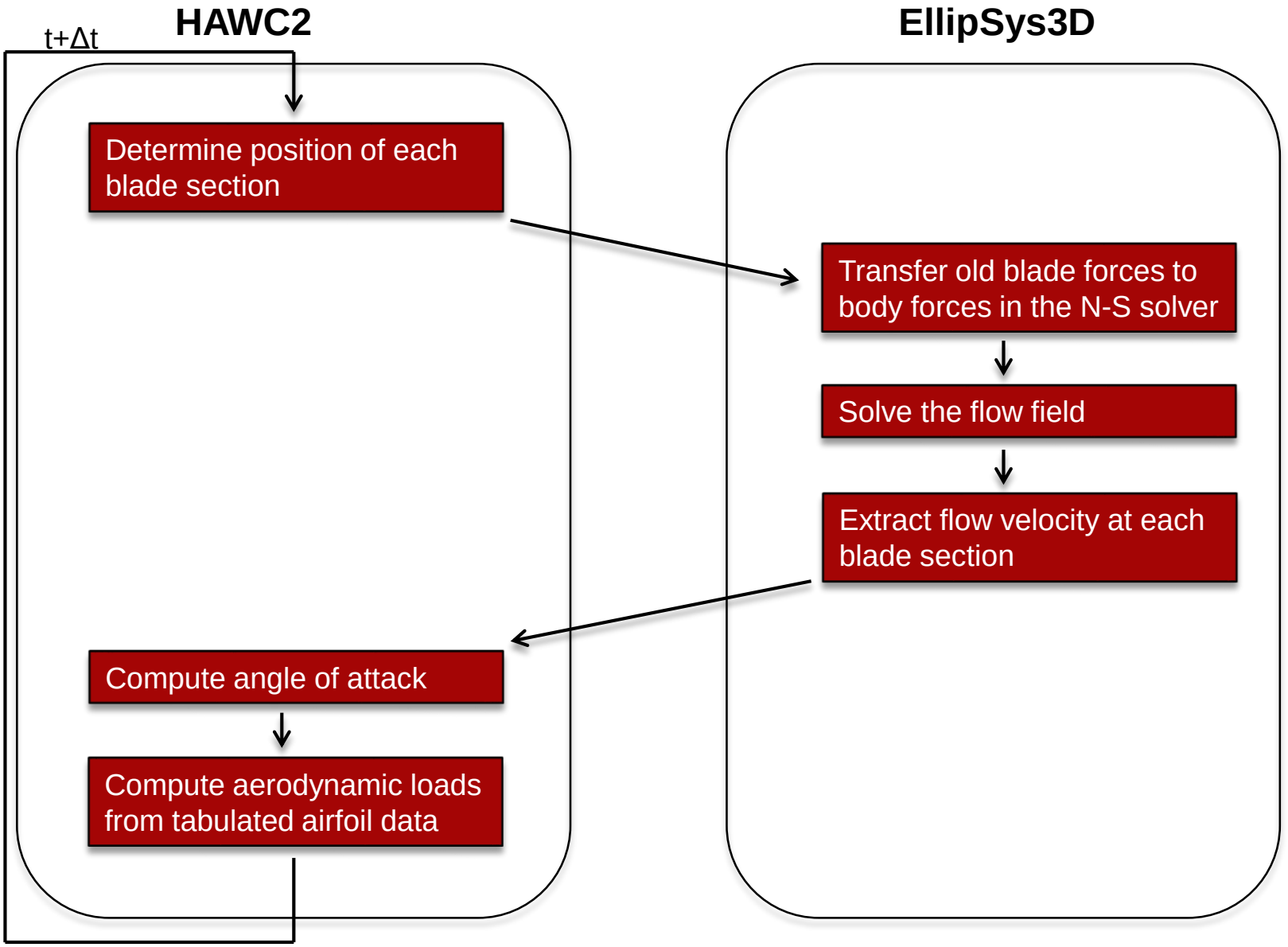

Validation: Simulation of NREL 5MW wind turbine

- Wind speed: V_∞ = 8 m/s
- Rotational speed Ω = 0.964 rad/s
- Blade loading determined from airfoil data
- Stiff blades, no tower

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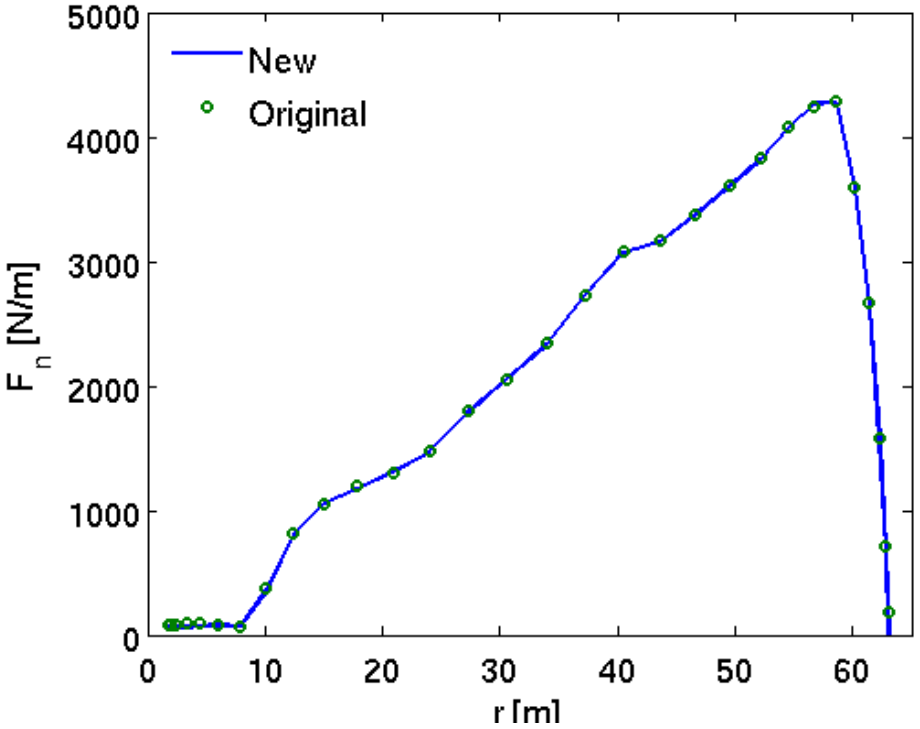
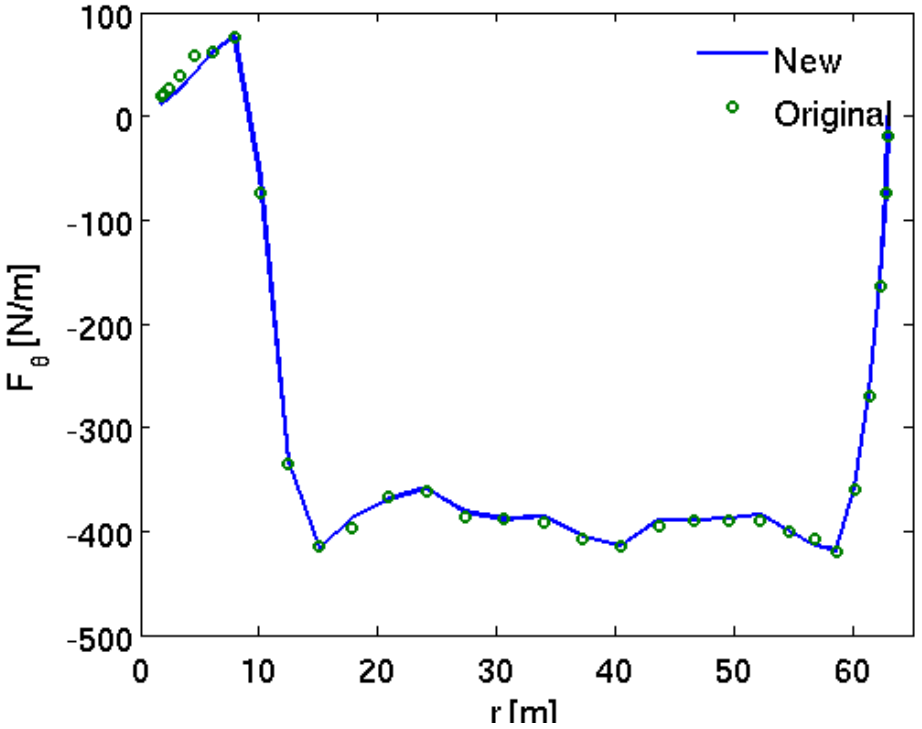
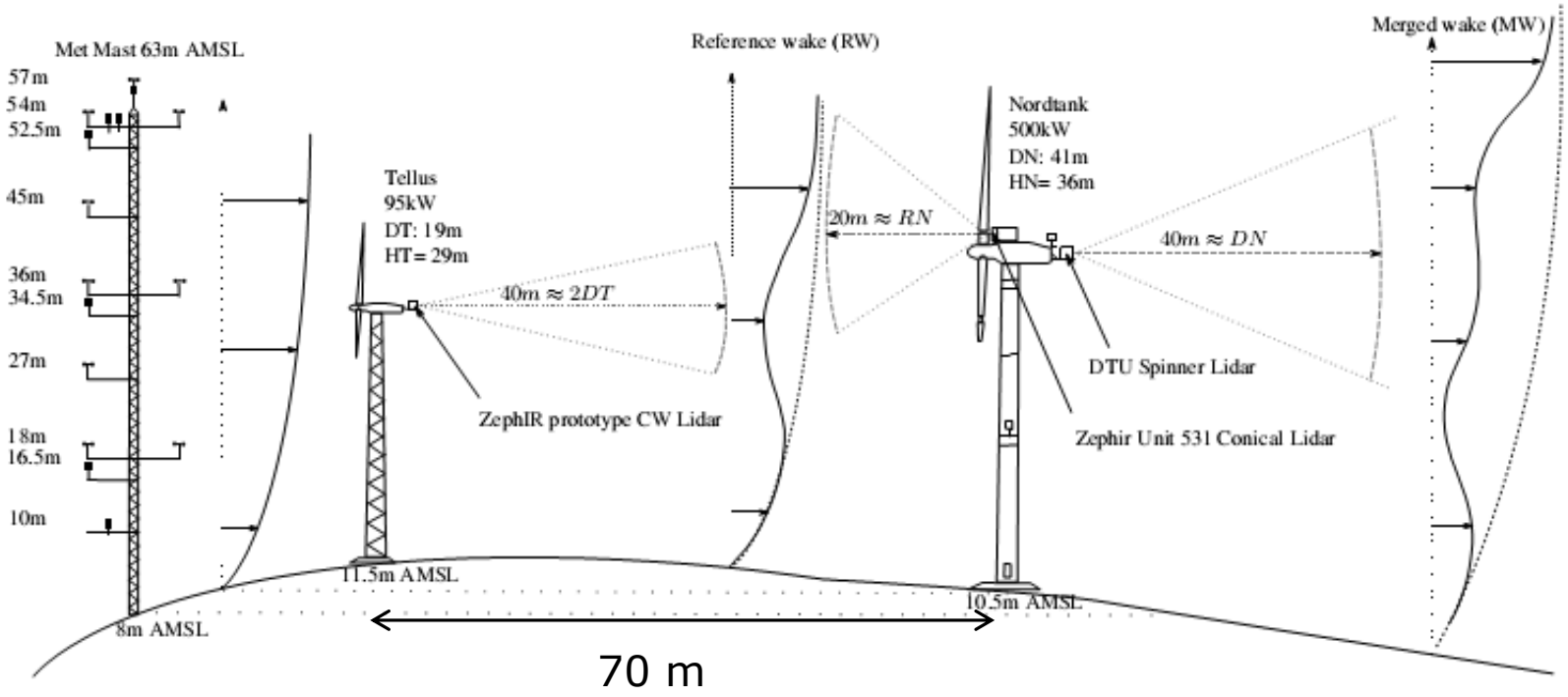
Good agreement!





Results: HAWC-AL Simulations of Wake Interaction

- Wake interaction between the 95 kW Tellus turbine and the 500 kW Nordtank turbine
- Wind speed: V_∞ = 8 m/s (no shear)
- Cubic mesh with side length 512.5 m
- Number of cells $96 \cdot 96 \cdot 128 = 1.18 \cdot 10^6$
- Ground modelled as flat symmetry surface



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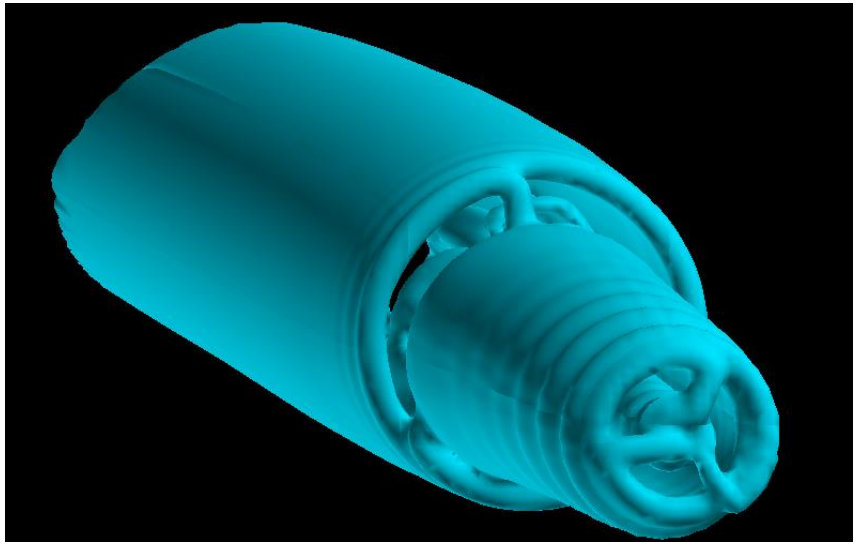
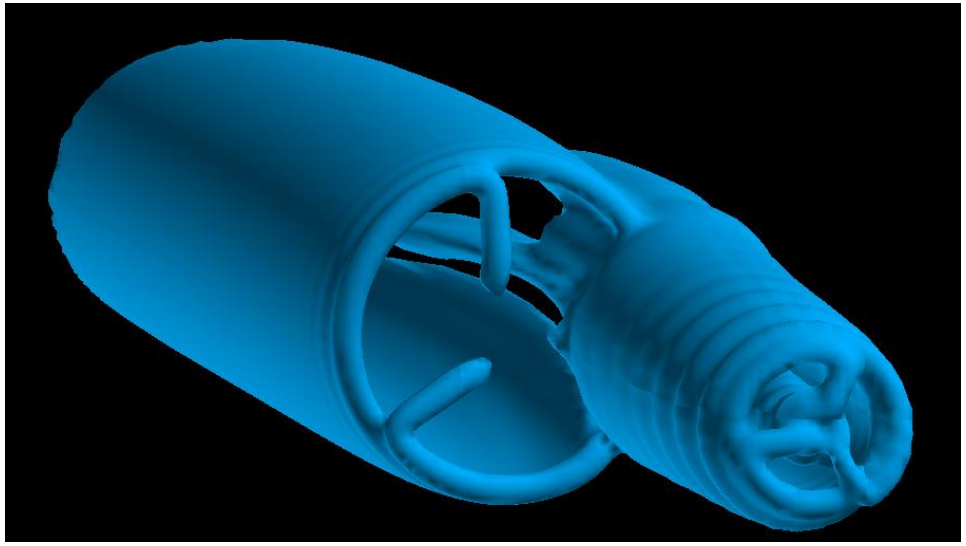
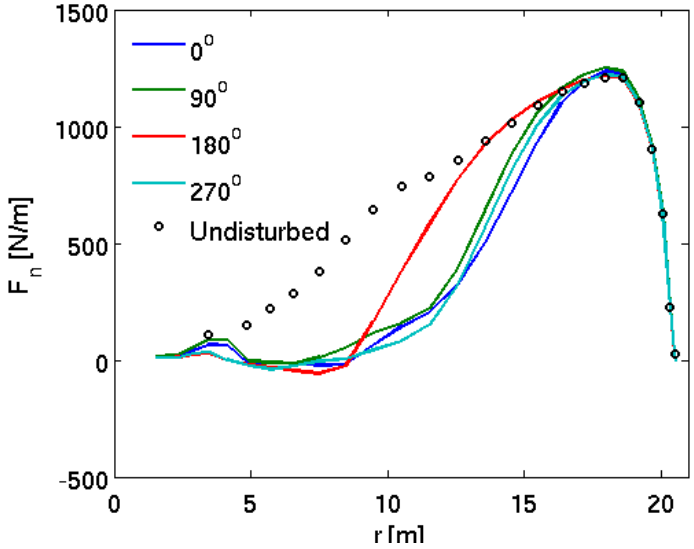


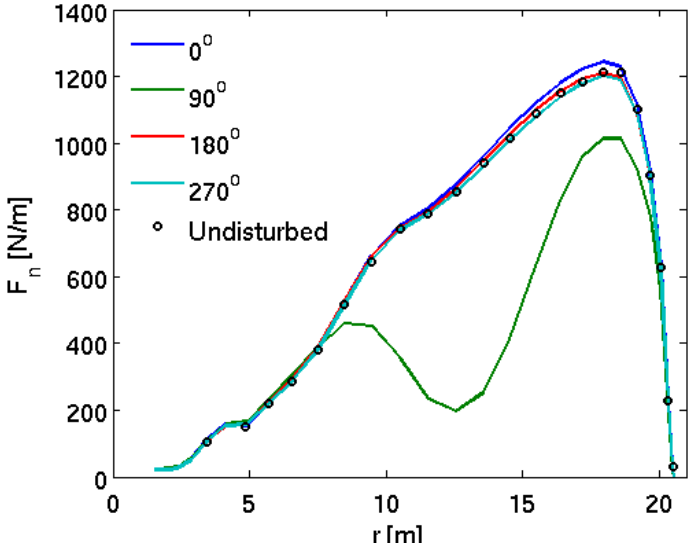
Full wake

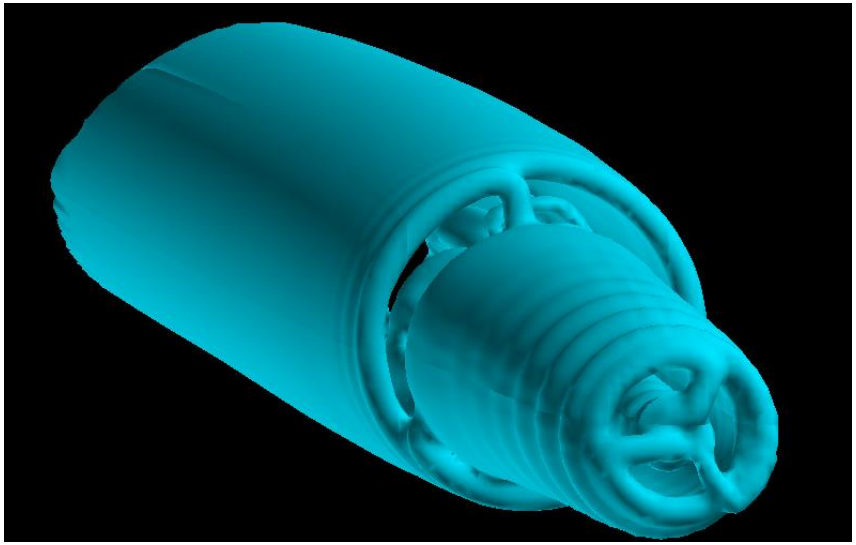


Partial wake

Results: HAWC-AL Simulations of Wake Interaction







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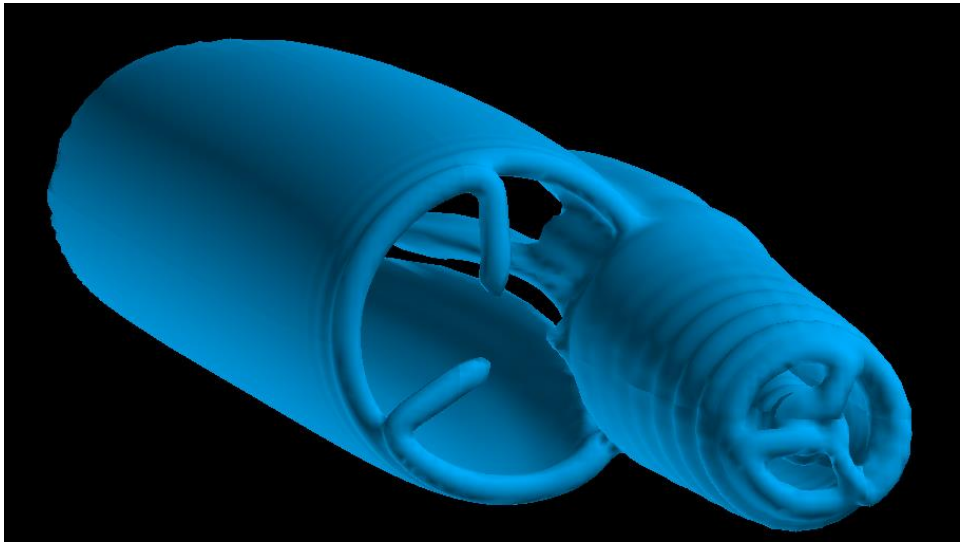

Partial wake

Conclusions & Future work

- The actuator line method has been coupled with the HAWC2 code
- A standard HAWC2 htc input file is used to defined the rotor for the coupled simulations
- The coupling can handle a multiple of different types of turbines
- Next step is to couple the AD with HAWC2