Wind turbine research activity at University of Padova

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1. Research activities

COMETES research group has several years of experience in the study of wind turbines design:

- 1D BEM model and 2D-3D CFD models (ANSYS Fluent, OpenFOAM)
- Aero-structural analysis and multi-objective optimisation
- Fully automatic OpenSource environment for HAWT / VAWT aerodynamic analysis
- Unsteady analysis of wind turbine operating under gust conditions

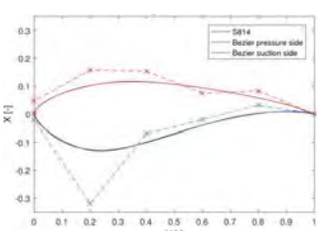
2. The BEM method

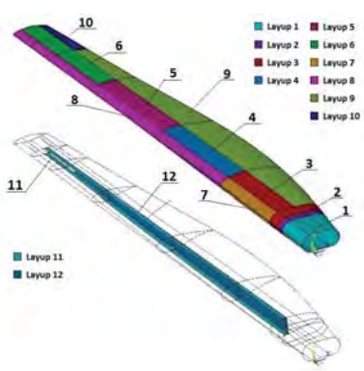
- **Fast** and **accurate** estimation of aerodynamic performance
- Negligible computational effort compared to a 3D CFD
- BEM + panel code (e.g. xFoil): forces for different rotational speeds
- Forces integral along radius: net thrust of the blade

3. Multi-objective optimisation

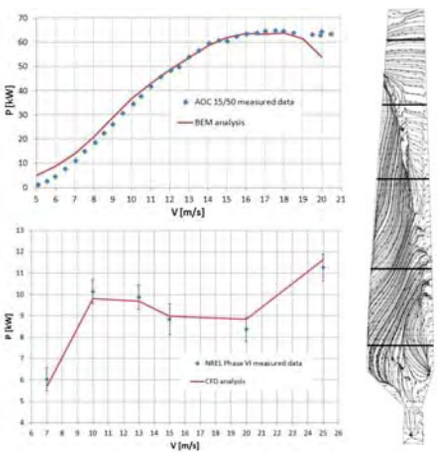
The optimisation of the wind turbine design is usually carried using the evolutive multi-objective **genetic algorithms**:

- Mathematical reconstitution of the airfoil using Bezier curve or B-Spline
- Several objectives: structural, aerodynamic and economics
- Both low and high fidelity methods for performance estimation





4. Validations of CFD and BEM models



Validation of steady / unsteady **RANS CFD** models and **BEM** model using data of SANDIA and NREL turbines:

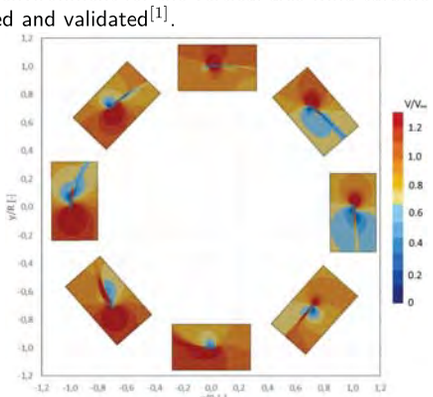
- Power curve
- Stall development
- Turbulence model influence
- Grid sensitivity
- FEM analysis

5. VAWT optimisation: an open-source toolbox

A fully automated open-source environment for the vertical axis wind turbine optimization has been developed and validated[1].

The modules involved are:

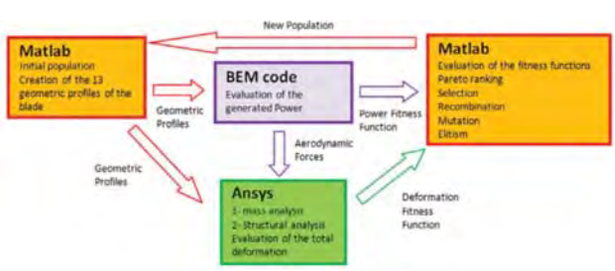
- **Dakota**: Optimization setting
- **Salome**: Geometry generation Mesh creation
- **OpenFOAM**: URANS CFD analysis
- **ParaView**: Post-Processing



6. The SOCRATE algorithm

SOCRATE (**Structural Optimisation for Composite Rotor Air TurbinE**): multi-disciplinary and multi-objective optimisation of wind turbines[2].

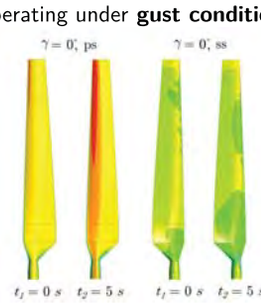
- Different parametrization techniques: select the layout of the composite structure of the blade (materials, fibre orientations, thickness, position of reinforcements).
- Multi-objective optimisation: structural objectives (maximum tip deformation, flapwise and edgewise rigidity) and aerodynamic objectives (Annual Energy Production, Cost Of Energy)

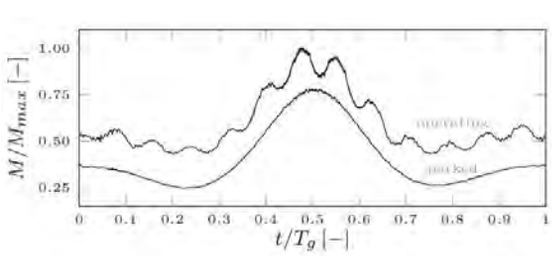


7. Wind gust operating conditions

Aerodynamic analysis of a small HAWT operating under **gust conditions**[3]:

- Wind gust: short and strong peak in wind velocity
- Extreme Operating Gust wind velocity profile from IEC 61400-2
- Unsteady CFD using moving mesh and variable wind profile
- Stress analysis at the blade root following IEC guidelines





8. References

[1] A. Dal Monte, *Development of an open source environment for the aero-structural optimization of wind turbines*, Ph.D. Thesis, 2017.

[2] A. Dal Monte, S. De Betta, M. R. Castelli, E. Benini, *Proposal for a coupled aerodynamic–structural wind turbine blade optimization*, Composite Structures, 159, 144-156, 2017.

[3] L. Menegozzo, A. Dal Monte, E. Benini, A. Benato, *Small wind turbines: a numerical study for aerodynamic performance assessment under gust conditions*. Renewable Energy, 121, 123 - 132, 2018