

Tip design To Optimize wind turbine blade

Publieke samenvatting / Public summary

A number of recent conceptual and experimental studies have shown blades based on curved tips (i.e., winglets and sweep) to be more effective, than the straight counterpart, in increasing the power production subject to load constraints. In addition, the design of winglets and sweep would allow engineers to explore the possibility to achieve passive load alleviation through bend-twist coupling.

Traditionally, the Blade Element Momentum (BEM) method has been used to determine rotor power and wind loading, of which the validity of application is limited to blade planforms with a straight blade axis. Computation Fluid Dynamics (CFD) has enabled quantification of the aerodynamics of more exotic curved blade planforms, allowing one to evaluate power performance in uniform steady conditions. Optimizing a curved blade shape using these methods is however still too costly in terms of computational power. Free Vortex Wake (FVW) methods provide an interesting alternative for optimization of a curved blade shape in terms of rotor power and blade loading at acceptable accuracy and computational cost, allowing wind turbine blade designers to unlock the real potential of these innovations. The latest developments at TNO have made it possible to determine aero-elastic wind turbine performance using a FVW method, which is a unique opportunity to develop a more mature design methodology for the abovementioned concepts.

Projectinformatie / Project information

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The main goal of the TipTOP project is to support the wind energy industry to design more efficient blades based on curved tips. To achieve the project goal, the consortium has developed a new method to optimize large blade planform design which is based on tips implementing sweep and/or winglets. Moreover, the project has developed and demonstrated an innovative extension for wind turbine blades based on a winglet, aiming at increasing the energy output of a wind turbine rotor, while constraining the blade loads to remain within certain limits.

Designing wind turbine blade tips implementing winglets and/or sweep is a challenging task. Through this project, the consortium has tackled important weaknesses in the state-of-the-art methodologies used to design curved blades, especially the lack of accurate and affordable methodologies to integrate aerodynamics and structure (i.e., aeroelasticity). Within the TipTOP project, the consortium has coupled the TNO's Aero-Module (AM) which contains the FVW code named AWSM to the open-source structural code OpenFAST. This has resulted in an advanced aeroelastic tool which allows engineers to design curved tips, considering realistic load cases.

Within TipTOP's first work package, TNO's state-of-the-art aerodynamic solver AM has been coupled to NREL's OpenFAST to create a new powerful tool for the aeroelastic modelling of modern wind turbines. This tool combines the aerodynamic accuracy and the unique validation record of AM with the great flexibility and the open-source development of OpenFAST, allowing to perform high accuracy aero-hydro-servo-elastic simulations of onshore/offshore wind turbines and their fixed/floating substructures. Using the FVW method implemented in AM, OpenFAST/AM makes the aeroelastic assessment of unconventional blade shapes possible, allowing to prove the impact of innovative design concepts (e.g. winglets, swept

blades) on realistic conditions. The coupling has been successfully validated and verified against experimental measurements as well as numerical results from other aeroelastic tools, and it has been shown to give a reliable option to perform design load case calculations of horizontal axis wind turbines.

Within the framework of TipTOP's second work package, we have redesigned the tip region of an existing blade by means of a winglet-like shape. The design exercise has aimed at maximizing the blade torque without increasing the rotor diameter. In order to assess the benefit of using such an unconventional shape, we have redesigned the tip part of the same baseline blade using a standard straight solution. To allow us for a fair comparison, both straight and wingletted blade tips have been designed consistently through the same objectives. The tip design and assessment have been carried out considering the aerodynamics only using AWSM. The results have shown that the wingletted blade achieves an increase in torque of around 1.2% and a reduction in flapwise bending moment of around 0.9% with respect to the straight counterpart. The reasons behind the more favorable aerodynamic conditions tied to the winglet design are related to a weaker wake vorticity system released around the tip region, which is associated with reduced tip losses.

To verify FVW simulations of curved blades, we have performed a study of the performance of the AWSM code in simulating the case of winglets mounted on wind turbines. AWSM results have been compared with results of normal and tangential forces and circulation distribution from a validated OpenFOAM's CFD model. The results have shown that over the outboard section of the blade and over the span of the winglet, AWSM performs well in predicting the performance of the blade-winglet configuration. This study has shown that AWSM is a reliable tool for the design and

optimization of winglets on wind turbine blades at a much lower cost than higher fidelity methods like CFD.

De data in deze applicatie is afkomstig van de Rijksdienst voor Ondernemend Nederland (RVO) en wordt in samenwerking met de Topsector Energie ontsloten.

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