Aerodynamic Design Optimization Of Wind Turbine Rotors

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Aerodynamic Design Optimization Of Wind Turbine Rotors ***2023-02-13***

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Enhanced Layout Optimization and Wind Aerodynamic Models for Wind Farm Design Springer
This thesis focuses on the study and improvement of the techniques involved on a virtual platform for the simulation of the Aerodynamics of Horizontal Axis Wind Turbines, with the ultimate objective of making Wind Energy more competitive. Navier-Stokes equations govern Aerodynamics, which is an unresolved and very active field of research due to the current inability to capture the relevant the scales both in time and space for nowadays industrial-size machines (with rotors over 100 m in diameter). Therefore, there is a need to aim at a combination of engineering and scientific models. The structure of this thesis is designed in accordance to the previous fact, so there are clearly two parts or approaches within the conducted research: zero dimensional models and CFD based analysis. For those zero-dimensional and (computationally) cheaper approach, the efforts done were the next: visualization and side improvements on the well known BEM code for pre-design purposes; designing an AeroElectric coupled algorithm to merge BEM with simple generator models that exclude details on electric circuits; designing a C++ code to study the dynamics of wind turbines coupling different component models; implementation of energy production based algorithms to optimize blades pre-designed

with BEM, given the wind resources at the real location. CFD-based analysis are meant to be the tools to design wind turbines in the future. Nowadays and for the years to come, they are and will be under ongoing research. The efforts done to this rescpect have been the next: exploration, implementation and analysis of Non-Inertial Reference Frame, Immersed Boundary Method, Sliding Meshes. Additionally, Adaptive Mesh Refinement and Wall Model LES methods have been explored too.

Wind Turbine Aerodynamics and Vorticity-Based Methods Academic Press

This book is an introduction to wind turbine aerodynamics for professionals and students with a diverse range of backgrounds. It is a self-contained textbook that shows how to progress from the basics of fluid mechanics to modern wind turbine blade design. It presents the fundamentals of fluid dynamics and inflow conditions, as well as extensive information on theories describing the aerodynamics of wind turbines. After examining a number of related experiments, the book applies the lessons learned to blade design. The text of this 3rd edition has been thoroughly revised, and the book includes a new section on aerodynamic design and optimization.

Aerodynamic Design Optimization Using the Navier-Stokes and Adjoint Equations Independently Published

Innovation in Wind Turbine Design addresses the fundamentals of design, the reasons behind design choices, and describes the methodology for evaluating innovative systems and components. Always referencing a state of the art system for comparison, Jamieson discusses the basics of wind turbine theory and design, as well as how to apply existing engineering knowledge to further advance the technology, enabling the reader to gain a thorough understanding of current technology before assessing where it can go in the future. Innovation in Wind Turbine Design is divided into four main sections covering design background, technology evaluation, design themes and innovative technology examples: Section 1 reviews aerodynamic theory and the optimization of rotor design, discusses wind energy conversion systems, drive trains, scaling issues, offshore wind turbines, and concludes with an overview of technology trends with a glimpse of possible future technology Section 2 comprises a global view of the multitude of design options for wind turbine systems and develops evaluation methodology, including cost of energy assessment with some specific examples Section 3 discusses recurrent design themes such as blade number, pitch or stall, horizontal or vertical axis Section 4 considers examples of innovative technology with case studies from real-life commercial clients. This groundbreaking synopsis of the state of the art in wind turbine design is must-have reading for professional wind engineers, power engineers and turbine designers, as well as consultants, researchers and academics working in renewable energy.

Aerodynamic Design Optimization of Proprotors for Convertible-rotor Concepts LAP Lambert Academic Publishing

This book on wind turbine aerodynamics is the first book in a series of books on wind power by the author. The books are an attempt to present a simplified explanation of wind power technology without sacrificing an in-depth understanding of the subject matter.

New Design Concepts for High Speed Air Transport BoD – Books

on Demand
Wind turbines are one of the most promising renewable energy technologies, and this motivates fertile research activity about developments in power optimization. This topic covers a wide range of aspects, from the research on aerodynamics and control design to the industrial applications about on-site wind turbine performance control and monitoring. This Special Issue collects seven research papers about several innovative aspects of the multi-faceted topic of wind turbine power optimization technology. The seven research papers deal respectively with the aerodynamic optimization of wind turbine blades through Gurney flaps; optimization of blade design for large offshore wind turbines; control design optimization of large wind turbines through the analysis of the competing objectives of energy yield maximization and fatigue loads minimization; design optimization of a tension leg platform for floating wind turbines; innovative methods for the assessment of wind turbine optimization technologies operating on site; optimization of multiple wake interactions modeling through the introduction of a mixing coefficient in the energy balance method; and optimization of the dynamic stall control of vertical-axis wind turbines through plasma actuators. This Special Issue presents remarkable research activities in the timely subject of wind turbine power optimization technology, covering various aspects. The collection is believed to be beneficial to readers and contribute to the wind power industry.

Introduction to Wind Turbine Aerodynamics Walter de Gruyter GmbH & Co KG
This title includes a number of Open Access chapters. This important book presents a selection of new research on wind turbine technology, including aerodynamics, generators and gear systems, towers and foundations, control systems, and environmental issues. This informative book: • Introduces the principles of wind turbine design • Presents methods for analysis of wind turbine performance • Discusses approaches for wind turbine improvement and optimization • Covers fault detection in wind turbines • Describes mediating the adverse effects of wind turbine use and installation

CAN-DO (CFD-based Aerodynamic Nozzle Design and Optimization) Program for Supersonic/hypersonic Wind Tunnels Springer
In order to improve energy capture and reduce the cost of wind energy, in the past few decades wind turbines have grown significantly larger. As their blades get longer, the design of the inboard region (near the blade root) becomes a trade-off between competing structural and aerodynamic requirements. State-of-the-art blades require thick airfoils near the root to efficiently support large loads inboard, but those thick airfoils have inherently poor aerodynamic performance. New designs are required to circumvent this design compromise. One such design is the "biplane blade", in which the thick airfoils in the inboard region are replaced with thinner airfoils in a biplane configuration. This design was shown previously to have significantly increased structural performance over conventional blades. In addition, the biplane airfoils can provide increased lift and aerodynamic efficiency compared to thick monoplane inboard airfoils, indicating a potential for increased power extraction. This work investigates the fundamental aerodynamic

aspects, aerodynamic design and performance, and optimal structural design of the biplane blade. First, the two-dimensional aerodynamics of biplanes with relatively thick airfoils are investigated, showing unique phenomena which arise as a result of airfoil thickness. Next, the aerodynamic design of the full biplane blade is considered. Two biplane blades are designed for optimal aerodynamic loading, and their aerodynamic performance quantified. Considering blades with practical chord distributions and including the drag of the mid-blade joint, it is shown that biplane blades have comparable power output to conventional monoplane designs. The results of this analysis also show that the biplane blades can be designed with significantly less chord than conventional designs, a characteristic which enables larger blade designs. The aerodynamic loads on the biplane blades are shown to be increased in gust conditions and decreased under extreme conditions. Finally, considering these aerodynamic loads, the blade mass reductions achievable by biplane blades are quantified. The internal structure of the biplane blades are designed using a multi-disciplinary optimization which seeks to minimize mass, subject to constraints which represent realistic design requirements. Using this approach, it is shown that biplane blades can be built more than 45% lighter than a similarly-optimized conventional blade; the reasons for these mass reductions are examined in detail. As blade length is increased, these mass reductions are shown to be even more significant. These large mass reductions are indicative of significant cost of electricity reductions from rotors fitted with biplane blades. Taken together, these results show that biplane blades are a concept which can enable the next generation of larger wind turbine rotors.

Detailed Aerodynamic Design Optimization of an RLV Turbine
John Wiley & Sons
Wind-Turbine Aerodynamics is a self-contained textbook which shows how to come from the basics of fluid mechanics to modern wind turbine blade design. It presents a fundamentals of fluid dynamics and inflow conditions, and gives a extensive introduction into theories describing the aerodynamics of wind turbines. After introducing experiments the book applies the knowledge to explore the impact on blade design.The book is an introduction for professionals and students of very varying levels.

Wind Turbine Design Simplified - Aerodynamics Springer
Aerodynamics of Wind Turbines is the established essential text for the fundamental solutions to efficient wind turbine design. Now in its second edition, it has been entirely updated and substantially extended to reflect advances in technology, research into rotor aerodynamics and the structural response of the wind turbine structure. Topics covered include increasing mass flow through the turbine, performance at low and high wind speeds, assessment of the extreme conditions under which the turbine will perform and the theory for calculating the lifetime of the turbine. The classical Blade Element Momentum method is also covered, as are eigenmodes and the dynamic behaviour of a turbine. The new material includes a description of the effects of the dynamics and how this can be modelled in an ?aeroelastic code?, which is widely used in the design and verification of modern wind turbines. Further, the description of how to calculate the vibration of the whole construction, as well as the time varying loads, has been substantially updated.

Towards a Virtual Platform for Aerodynamic Design, Performance Assessment and Optimization of Horizontal Axis Wind Turbines Routledge
Fundamentals of Wind Farm Aerodynamic Layout Design, Volume Four provides readers with effective wind farm design and layout guidance through algorithm optimization, going beyond other references and general approaches in literature. Focusing on interactions of wake models, designers can combine numerical schemes presented in this book which also considers wake models' effects and problems on layout optimization in order to simulate and enhance wind farm designs. Covering the aerodynamic modeling and simulation of wind farms, the book's authors include experimental tests supporting modeling simulations and tutorials on the simulation of wind turbines. In addition, the book includes a CFD technique designed to be more computationally efficient than currently available techniques, making this book ideal for industrial engineers in the wind industry who need to produce an accurate simulation within limited timeframes. Features novel CFD modeling Offers global case studies for turbine wind farm layouts Includes tutorials on simulation of wind turbine using OpenFoam
Robust Aerodynamic Design of Mars Exploratory Airplane Wing Springer
Modern and larger horizontal-axis wind turbines with power capacity reaching 15 MW and rotors of more than 235-meter diameter are under continuous development for the merit of minimizing the unit cost of energy production (total annual cost/annual energy produced). Such valuable advances in this competitive source of clean energy have made numerous research contributions in developing wind industry technologies worldwide. This book provides important information on the optimum design of wind energy conversion systems (WECS) with a comprehensive and self-contained handling of design fundamentals of wind turbines. Section I deals with optimal production of energy, multi-disciplinary optimization of wind turbines, aerodynamic and structural dynamic optimization and aeroelasticity of the rotating blades. Section II considers operational monitoring, reliability and optimal control of wind turbine components.
Aerodynamic Design and Optimization in One Shot Springer Nature
The book introduces the fundamentals of fluid-mechanics, momentum theories, vortex theories and vortex methods necessary for the study of rotors aerodynamics and wind-turbines aerodynamics in particular. Rotor theories are presented in a great level of details at the beginning of the book. These theories include: the blade element theory, the Kutta-Joukowski theory, the momentum theory and the blade element momentum method. A part of the book is dedicated to the description and implementation of vortex methods. The remaining of the book focuses on the study of wind turbine aerodynamics using vortex-theory analyses or vortex-methods. Examples of vortex-theory applications are: optimal rotor design, tip-loss corrections, yaw-models and dynamic inflow models. Historical derivations and recent extensions of the models are presented. The cylindrical vortex model is another example of a simple analytical vortex model presented in this book. This model leads to the development of different BEM models and it is also used to

provide the analytical velocity field upstream of a turbine or a wind farm under aligned or yawed conditions. Different applications of numerical vortex methods are presented. Numerical methods are used for instance to investigate the influence of a wind turbine on the incoming turbulence. Sheared inflows and aero-elastic simulations are investigated using vortex methods for the first time. Many analytical flows are derived in details: vortex rings, vortex cylinders, Hill's vortex, vortex blobs etc. They are used throughout the book to devise simple rotor models or to validate the implementation of numerical methods. Several Matlab programs are provided to ease some of the most complex implementations.

Aircraft Aerodynamic Design CRC Press

This book on wind turbine aerodynamics is the first book in a series of books on wind power by the author. The books are an attempt to present a simplified explanation of wind power technology without sacrificing an in-depth understanding of the subject matter. Wind turbines produce electrical or mechanical power by extracting energy from the wind. Although many early wind turbines relied upon drag forces to produce power, modern turbines rely upon aerodynamic lift forces. Lift forces are generated by airfoils. In this book we will explore the aerodynamic principles that govern how and why airfoils are able to produce lift. We will discuss lift and drag and how wind turbine rotors extract energy from the wind. We will look at airfoil types and some of the characteristics that affect their suit¬ability for use on wind turbine rotors. Additionally, we will learn about the effects of blade speed, numbers of blades and blade shape. We will see how power production, the physical limits on wind turbine efficiency and maximum power extraction from the wind are determined.

Innovation in Wind Turbine Design Lulu.com

This handbook provides both a comprehensive overview and deep insights on the state-of-the-art methods used in wind turbine aerodynamics, as well as their advantages and limits. The focus of this work is specifically on wind turbines, where the aerodynamics are different from that of other fields due to the turbulent wind fields they face and the resultant differences in structural requirements. It gives a complete picture of research in the field, taking into account the different approaches which are applied. This book would be useful to professionals, academics, researchers and students working in the field.

Introduction to Wind Turbine Aerodynamics Wiley-Blackwell

A review of the aerodynamics, design and analysis, and optimization of wind turbines, combined with the author’s unique software Aerodynamics of Wind Turbines is a comprehensive introduction to the aerodynamics, scaled design and analysis, and optimization of horizontal-axis wind turbines. The author –a noted expert on the topic – reviews the fundamentals and basic physics of wind turbines operating in the atmospheric boundary layer. He then explores more complex models that help in the aerodynamic analysis and design of turbine models. The text contains unique chapters on blade element momentum theory, airfoil aerodynamics, rotational augmentation, vortex-wake methods, actuator-line modeling, and designing aerodynamically scaled turbines for model-scale experiments. The author clearly demonstrates how effective analysis and design principles can be used in a wide variety of applications and operating conditions.

The book integrates the easy-to-use, hands-on XTurb design and analysis software that is available on a companion website for facilitating individual analyses and future studies. This component enhances the learning experience and helps with a deeper and more complete understanding of the subject matter. This important book: Covers aerodynamics, design and analysis and optimization of wind turbines Offers the author’s XTurb design and analysis software that is available on a companion website for individual analyses and future studies Includes unique chapters on blade element momentum theory, airfoil aerodynamics, rotational augmentation, vortex-wake methods, actuator-line modeling, and designing aerodynamically scaled turbines for model-scale experiments Demonstrates how design principles can be applied to a variety of applications and operating conditions Written for senior undergraduate and graduate students in wind energy as well as practicing engineers and scientists, Aerodynamics of Wind Turbines is an authoritative text that offers a guide to the fundamental principles, design and analysis of wind turbines.

Toward the Aerodynamic Shape Optimization of Wind Turbine Profiles John Wiley & Sons

Optimal aircraft design is impossible without a parametric representation of the geometry of the airframe. We need a mathematical model equipped with a set of controls, or design variables, which generates different candidate airframe shapes in response to changes in the values of these variables. This model's objectives are to be flexible and concise, and capable of yielding a wide range of shapes with a minimum number of design variables. Moreover, the process of converting these variables into aircraft geometries must be robust. Alas, flexibility, conciseness and robustness can seldom be achieved simultaneously. Aircraft Aerodynamic Design: Geometry and Optimization addresses this problem by navigating the subtle trade-offs between the competing objectives of geometry parameterization. It beginswith the fundamentals of geometry-centred aircraft design, followed by a review of the building blocks of computational geometries, the curve and surface formulations at the heart of aircraft geometry. The authors then cover a range of legacy formulations in the build-up towards a discussion of the most flexible shape models used in aerodynamic design (with a focus on lift generating surfaces). The book takes a practical approach and includes MATLAB®, Python and Rhinoceros® code, as well as 'real-life' example case studies. Key features: Covers effective geometry parameterization within the context of design optimization Demonstrates how geometry parameterization is an important element of modern aircraft design Includes code and case studies which enable the reader to apply each theoretical concept either as an aid to understanding or as a building block of their own geometry model Accompanied by a website hosting codes Aircraft Aerodynamic Design: Geometry and Optimization is a practical guide for researchers and practitioners in the aerospace industry, and a reference for graduate and undergraduate students in aircraft design and multidisciplinary design optimization.

Wind Turbine Airfoils and Blades Cambridge University Press

The state-of-the-practice methods for aerodynamic design of wind turbine blads use linearized blade element momentum theory (BEM) to optimize the twist and chord profiles from a pre-selected set of 2D airfoil shapes. In this work, we apply invertible neural network (INN) tools to enable the rapid inverse aerodynamic design of wind turbine blades including component airfoils. The INN is trained on data obtained through the use of robust automated mesh generation and the HAMSTR computational fluid dynamics solver with advanced turbulence and transition models validated for turbine applications. Our design technique is a significant improvement over the state-of-the-practice linearized blade element momentum (BEM) techniques in capturing 3D nonlinear aerodynamic effects that are critical for optimal design of the rotors. This is made possible by developing sparse, invertible neural networks (INNs) for inverse design and optimization that realize a 100x cost reduction compared to adjoint-based computational fluid dynamics (CFD) approaches, while enabling increased robustness of the final design. We demonstrate the INN tool for design of a section of the NREL 5-MW blade. All generated shapes satisfy the desired aerodynamic characteristics, demonstrating the success of the INN approach for inverse design of wind turbine blades.

Wind Turbine Power Optimization Technology Springer Nature

Wind Turbine Airfoils and Blades introduces new ideas in the design of wind turbine airfoils and blades based on functional integral theory and the finite element method, accompanied by results from wind tunnel testing. The authors also discuss the optimization of wind turbine blades as well as results from aerodynamic analysis. This book is suitable for researchers and engineers in aeronautics and can be used as a textbook for graduate students.

Introduction to Wind Turbine Aerodynamics MDPI

This book offers an introduction to the topic for professionals and students with a diverse range of backgrounds. Wind Turbine Aerodynamics is a self-contained textbook that shows how to progress from the basics of fluid mechanics to modern wind turbine blade design. It presents the fundamentals of fluid dynamics and inflow conditions, as well as extensive information on theories describing the aerodynamics of wind turbines. After examining a number of related experiments, the book applies the lessons learned to blade design. The text of the 2nd edition has been thoroughly revised, with a focus on improved readability. The examples and solutions have been extended to explain each problem in much greater detail.

WInd Turbine Design Simplified

The proposed project is motivated by the need to develop wake models and optimization algorithms that can accurately capture the wake losses in an array of wind turbines and optimize the turbine placements. In the past 4 years, we have developed capabilities to improve the layout design of wind farms located on complex terrains, as contributions from four major tasks. The outcome of the first task was the creation of a wake interaction model capable of describing the effects of overlapping wakes that can be used in combination with existing mathematical optimization tools for wind farm layout design. Such a model was derived and evaluated against existing wake interaction methods. This wake interaction model enables a mechanistic approach to account for multiple overlapping wakes while remaining compatible with established mathematical optimization methods. In the second task, this wake interaction model was used in conjunction with full-scale CFD simulations to design wind farm layouts. We developed an optimization algorithm that intelligently integrates a mathematical optimization approach to design wind farm layout on complex terrains with full-scale CFD simulations. The two subsequent tasks were focused on developing a wake model capable of producing comparable accuracy as full-scale CFD simulations but at a significantly lower computational cost. The third task focused on studying the effects of turbine blade geometry and atmospheric turbulence on turbine wake development. The findings of this step contributed to the fourth task of developing a new wake model capable of simulating wakes on complex terrains. This model has been validated against full-scale CFD simulations of a turbine placed on the terrain of the Gros-Morne Wind Farm in Quebec. The proposed model allows for fast simulation of wakes, making it ideal for designing wind farm layouts on complex terrains.