Wind Farm Modeling For Steady State And Dynamic Analysis

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Advances in Technology Development and Research
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Theory, Design and Application
Environmental Impacts of Wind-Energy Projects
Handbook of Clean Energy Systems, 6 Volume Set
Airborne Wind Energy
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Technologies, Design and Operation
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Wind Energy Explained
September 10, 1999 -- October 31, 2003
Simulation of Power System with Renewables

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Distribution Circuit Multi-time-scale Simulation Tool for Wind Turbine and Photovoltaic Integration Analysis Springer Science & Business Media
The wind turbine tower causes time-varying turbine blade loads and wake behavior; however, the interactions of the turbine blades with the tower are not accounted for in state-of-the-art computational fluid dynamic simulations of wind plants. In this thesis, a tower model is developed using the body-force method, specifically, the actuator line method. The actuator line method has been widely used to model wind turbine rotors in flow simulations of wind plants. The tower model is implemented into the full-scale NREL Phase VI turbine simulation under uniform inflow and steady yaw conditions. The simulation results, primarily the blade loads predictions along the turbine blades, are compared to wind tunnel test data from the NREL Phase VI Unsteady Aerodynamics Experiment. Quantitative comparisons against measured NREL data were performed for both spanwise and phase-averaged sectional blade loads as a function of rotor azimuth. The proposed tower model is well validated and be easily implemented by the wind energy community for use in both actuator line wind plant simulations and other fully blade-resolved wind turbine simulations.
Grid Integration and Dynamic Impact of Wind Energy IGI Global
Today's wind energy industry is at a crossroads. Global economic instability has threatened or eliminated many financial incentives that have been important to the development of specific markets. Now more than ever, this essential element of the world energy mosaic will require innovative research and strategic collaborations to bolster the industry as it moves forward. This text details topics fundamental to the efficient operation of modern commercial farms and highlights advanced research that will enable next-generation wind energy technologies. The book is organized into three sections, Inflow and Wake Influences on Turbine Performance, Turbine Structural Response, and Power Conversion, Control and Integration. In addition to fundamental concepts, the reader will be exposed to comprehensive treatments of topics like wake dynamics, analysis of complex turbine blades, and power electronics in small-scale wind turbine systems.
Modeling and Analysis of Doubly Fed Induction Generator Wind Energy Systems John Wiley & Sons
This book provides in-depth coverage of the latest research and development activities concerning innovative wind energy technologies intended to replace fossil fuels on an economical basis. A characteristic feature of the various conversion concepts discussed is the use of tethered flying devices to substantially reduce the material consumption per installed unit and to access wind energy at higher altitudes, where the wind is more consistent. The introductory chapter describes the emergence and economic dimension of airborne wind energy. Focusing on “Fundamentals, Modeling & Simulation”, Part I includes six contributions that describe quasi-steady as well as dynamic models and simulations of airborne wind energy systems or individual components. Shifting the spotlight to “Control, Optimization & Flight State Measurement”, Part II combines one chapter on measurement techniques with five chapters on control of kite and ground stations, and two chapters on optimization. Part III on “Concept Design & Analysis” includes three chapters that present and analyze novel harvesting concepts as well as two chapters on system component design. Part IV, which centers on “Implemented Concepts”, presents five chapters on established system concepts and one chapter about a subsystem for automatic launching and landing of kites. In closing, Part V focuses with four chapters on “Technology Deployment” related to market and financing strategies, as well as on regulation and the environment. The book builds on the success of the first volume “Airborne Wind Energy” (Springer, 2013), and offers a self-contained reference guide for researchers, scientists, professionals and students. The respective chapters were contributed by a broad variety of authors: academics, practicing engineers and inventors, all of whom are experts in their respective fields.
Modeling, Simulation and Optimization of Wind Farms and Hybrid Systems Anchor Academic Publishing (aap_verlag)
Wind Energy Systems: Modeling, Analysis and Control with DFIG provides key information on machine/converter modelling strategies based on space vectors, complex vector, and further frequency-domain variables. It includes applications that focus on wind energy grid integration, with analysis and control explanations with examples. For those working in the field of wind energy integration examining the potential risk of stability is key, this edition looks at how wind energy is modelled, what kind of control systems are adopted, how it interacts with the grid, as well as suitable study approaches. Not only giving principles behind the dynamics of wind energy grid integration system, but also examining different strategies for analysis, such as frequency-domain-based and state-space-based approaches. Focuses on real and reactive power control Supported by PSCAD and Matlab/Simulink examples Considers the difference in control objectives between ac drive systems and grid integration systems
Blade-Pitch Control for Wind Turbine Load Reductions Wiley-IEEE Press
The generation of electricity by wind energy has the potential to reduce environmental impacts caused by the use of fossil fuels. Although the use of wind energy to generate electricity is increasing rapidly in the United States, government guidance to help communities and developers evaluate and plan proposed wind-energy projects is lacking. Environmental Impacts of Wind-Energy Projects offers an analysis of the environmental benefits and drawbacks of wind energy, along with an evaluation guide to aid decision-making about projects. It includes a case study of the mid-Atlantic highlands, a mountainous area that spans parts of West Virginia, Virginia, Maryland, and Pennsylvania. This book will inform policy makers at the federal, state, and local levels.
Strategies for Voltage Control and Transient Stability Assessment BoD – Books on Demand
From the point of view of grid integration and operation, this monograph advances the subject of wind energy control from the individual-unit to the wind-farm level. The basic objectives and requirements for successful integration of wind energy with existing power grids are discussed, followed by an overview of the state of the art, proposed solutions and challenges yet to be resolved. At the individual-turbine level, a nonlinear controller based on feedback linearization, uncertainty estimation and gradient-based optimization is shown robustly to control both active and reactive power outputs of variable-speed turbines with doubly-fed induction generators. Heuristic coordination of the output of a wind farm, represented by a single equivalent turbine with energy storage to optimize and smooth the active power output is presented. A generic approximate model of wind turbine control developed using system identification techniques is proposed to advance research and facilitate the treatment of control issues at the wind-farm level. A supervisory wind-farm controller is then introduced with a view to maximizing and regulating active power output under normal operating conditions and unusual contingencies. This helps to make the individual turbines cooperate in such as way that the overall output of the farm accurately tracks a reference and/or is statistically as smooth as possible to improve grid reliability. The text concludes with an overall discussion of the promise of advanced wind-farm control techniques in making wind an economic energy source and beneficial influence on grid performance. The challenges that warrant further research are succinctly enumerated. Control and Operation of Grid-Connected Wind Farms is primarily intended for researchers from a systems and control background wishing to apply their expertise to the area of wind-energy generation. At the same time, coverage of contemporary solutions to fundamental operational problems will benefit power/energy engineers endeavoring to promote wind as a reliable and clean source of electrical power.
Major Issues, Contemporary Solutions, and Open Challenges John Wiley & Sons
A computational framework for aeroelastic analysis of Horizontal Axis Wind Turbines (HAWT's) is presented. The structural model is separated into multi-rigid-body and flexible-body parts. Equations

for the former are derived using Kane's method; and the flexible portions are assumed to be beam-like structures, described using a mixed formulation. The equations of motion are of a relatively low order in terms of geometrically-exact beam finite elements. The flexible and rigid subsystems are coupled with an aerodynamic model to form an aeroelastic analysis. A nonlinear, periodic, steady-state solution and a linearized transient solution about the periodic steady state are obtained. The computational framework for two-bladed, HAWT's is built using time finite elements over a half-period. The linearized ordinary differential equations have periodic coefficients in time, and a Floquet stability analysis for the linearized system is directly undertaken using periodic steady state results. Numerical results are presented for horizontal axis wind turbines including steady-state response and Floquet characteristic exponents and operating mode shapes. Effects on the dynamics of the system for pre-cone, rotor speed, teetering hinge lateral offset, teetering and yawing stiffness and damping, and composite blade properties are investigated. A user's guide for the computer program WTFlex is included in the appendix.
Modeling of Wind Parks for Steady State Short Circuit Studies BoD – Books on Demand
This book examines real-time models and advanced online applications that enhance reliability and resilience of the grid in real-time and near real-time environments. It is written by Peak Reliability engineers who worked on the creation of the West Wide System Model (WSM) and the implementation of advanced real-time operation situational awareness tools for reliability coordination function. The book looks at how a single Reliability Coordinator for the Western Interconnection did its work under normal and emergency conditions, providing a unique perspective on best practices and lessons learned from Peak's modeling and coordination efforts to create, maintain, and improve state-of-art new technology and algorithms to improve real-time operation situational awareness and Bulk Electric System (BES) grid resilience. Coverage includes practical experience of implementing real-time Energy Management System (EMS) Network Application, real-time voltage stability analysis, online transient stability analysis, synchrophasor technology, Dispatcher Training Simulator and EMS Cybersecurity & Inter-Control Center Communications Protocol (ICCP) implementation experience in a Reliability Coordinator Control Room setting. Explains how to operate a "green" grid and prevent new blackouts against uncertain operation conditions; Written by Peak Reliability engineers who worked on the creation of the West Wide System Model (WWSM); All material verified in practical system operations, or validated by real system measures and system events.
Doubly Fed Induction Machine World Scientific Publishing Europe Limited
Offshore Wind Farms: Technologies, Design and Operation provides the latest information on offshore wind energy, one of Europe's most promising and quickly maturing industries, and a potentially huge untapped renewable energy source which could contribute significantly towards EU 20-20-20 renewable energy generation targets. It has been estimated that by 2030 Europe could have 150GW of offshore wind energy capacity, meeting 14% of our power demand. Offshore Wind Farms: Technologies, Design and Operation provides a comprehensive overview of the emerging technologies, design, and operation of offshore wind farms. Part One introduces offshore wind energy as well as offshore wind turbine siting with expert analysis of economics, wind resources, and remote sensing technologies. The second section provides an overview of offshore wind turbine materials and design, while part three outlines the integration of wind farms into power grids with insights to cabling and energy storage. The final section of the book details the installation and operation of offshore wind farms with chapters on condition monitoring and health and safety, amongst others. Provides an in-depth, multi-contributor, comprehensive overview of offshore technologies, including design, monitoring, and operation Edited by respected and leading experts in the field, with experience in both academia and industry Covers a highly relevant and important topic given the great potential of offshore wind power in contributing significantly to EU 20-20-20 renewable energy targets
An Introduction Academic Press
This book will be focused on the modeling and control of the DFIM based wind turbines. In the first part of the book, the mathematical description of different basic dynamic models of the DFIM will be carried out. It will be accompanied by a detailed steady-state analysis of the machine. After that, a more sophisticated model of the machine that considers grid disturbances, such as voltage dips and unbalances will be also studied. The second part of the book surveys the most relevant control strategies used for the DFIM when it operates at the wind energy generation application. The control techniques studied, range from standard solutions used by wind turbine manufacturers, to the last developments oriented to improve the behavior of high power wind turbines, as well as control and hardware based solutions to address different faulty scenarios of the grid. In addition, the standalone DFIM generation system will be also analyzed.
Renewable Energy Systems John Wiley & Sons
The Handbook of Clean Energy Systems brings together an international team of experts to present a comprehensive overview of the latest research, developments and practical applications throughout all areas of clean energy systems. Consolidating information which is currently scattered across a wide variety of literature sources, the handbook covers a broad range of topics in this interdisciplinary research field including both fossil and renewable energy systems. The development of intelligent energy systems for efficient energy processes and mitigation technologies for the reduction of environmental pollutants is explored in depth, and environmental, social and economic impacts are also addressed. Topics covered include: Volume 1 - Renewable Energy: Biomass resources and biofuel production; Bioenergy Utilization; Solar Energy; Wind Energy; Geothermal Energy; Tidal Energy. Volume 2 - Clean Energy Conversion Technologies: Steam/Vapor Power Generation; Gas Turbines Power Generation; Reciprocating Engines; Fuel Cells; Cogeneration and Polygeneration. Volume 3 - Mitigation Technologies: Carbon Capture; Negative Emissions System; Carbon Transportation; Carbon Storage; Emission Mitigation Technologies; Efficiency Improvements and Waste Management; Waste to Energy. Volume 4 - Intelligent Energy Systems: Future Electricity Markets; Diagnostic and Control of Energy Systems; New Electric Transmission Systems; Smart Grid and Modern Electrical Systems; Energy Efficiency of Municipal Energy Systems; Energy Efficiency of Industrial Energy Systems; Consumer Behaviors; Load Control and Management; Electric Car and Hybrid Car; Energy Efficiency Improvement. Volume 5 - Energy Storage: Thermal Energy Storage; Chemical Storage; Mechanical Storage; Electrochemical Storage; Integrated Storage Systems. Volume 6 - Sustainability of Energy Systems: Sustainability Indicators, Evaluation Criteria, and Reporting; Regulation and Policy; Finance and Investment; Emission Trading; Modeling and Analysis of Energy Systems; Energy vs. Development; Low Carbon Economy; Energy Efficiencies and Emission Reduction. Key features: Comprising over 3,500 pages in 6 volumes, HCES presents a comprehensive overview of the latest research, developments and practical applications throughout all areas of clean energy systems, consolidating a wealth of information which is currently scattered across a wide variety of literature sources. In addition to renewable energy systems, HCES also covers processes for the efficient and clean conversion of traditional fuels such as coal, oil and gas, energy storage systems, mitigation technologies for the reduction of environmental pollutants, and the development of intelligent energy systems. Environmental, social and economic impacts of energy systems are also addressed in depth. Published in full colour throughout. Fully indexed with cross referencing within and between all six volumes. Edited by leading researchers from academia and industry who are internationally renowned and active in their respective fields. Published in print and online. The online version is a single publication (i.e. no updates), available for one-time purchase or through annual subscription.
Measurement, Calibration, and Design Academic Press
An estimate of the United States wind potential conducted in 2011 found that the energy available at an altitude of 80 meters is approximately triple the wind energy available 50 meters above ground. In 2012, 43% of all new electricity generation installed in the U.S. (13.1 GW) came from wind power. The majority of this power, 79%, comes from large utility scale turbines that are being manufactured at unprecedented sizes. Existing wind plants operate with a capacity factor of only approximately 30%. Measurements have shown that the turbulent wake of a turbine persists for many rotor diameters, inducing increased vibration and wear on downwind turbines. Power losses can be as high as 20-30% in operating wind plants, due solely to complex wake interactions occurring in wind plant arrays. It is my objective to accurately predict the generation and interaction of turbine wakes and their interaction with downwind turbines and topology by means of numerical simulation with high-performance parallel computer systems. Numerical simulation is already utilized to plan wind plant layouts. However, available computational tools employ severe geometric simplifications to model wake interactions and are geared to providing rough estimates on desktop PCs. A three dimensional simulation tool designed for modern parallel computers based upon lattice Boltzmann methods for fluid-dynamics, a general six-degree-of-freedom motion solver, and foundational beam solvers has been proposed to meet this simulation need. In this text, the software development, verification, and validation are detailed. Fundamental computational fluid dynamics issues of boundary conditions and turbulence modeling are examined through classic cases (Cavity, Jeffery-Hammel, Kelvin-Helmholtz, Pressure wave, Vorticity wave, Backward facing step, Cylinder in cross-flow, Airfoils, Tandem cylinders, and Turbulent flow over a hill) to asses the accuracy and computational cost of developed alternatives. Simulations of canonical motion (falling beam), fluid-structure-interaction cases (Hinged wing and Flexible pendulum), and realistic horizontal axis wind turbine geometries (Vestas v27, NREL 5MW, and MEXICO) are validated against benchmarks and experiments. Results from simulations of the three turbine array at the Scaled Wind Farm Test facility are presented for two steady wind conditions.
National Academies Press
A wind turbine is of course far more complicated than just a tower topped with a big fan, especially for the offshore ones. Wind energy as a green energy resource with zero fuel requirements, and thus no processing waste, has been assuming an increasingly important role in energy generation. Offshore wind farms with their steady output and low sensual impact have been gradually accepted by the public and authorities. Once built, the only cost for a wind farm is the operation and maintenance cost. Therefore, the question of how to reduce the failure rate and the operation and maintenance costs, and make offshore wind energy cheaper, is particularly pertinent, and is discussed in great detail here. This book details the various aspects of wind energy, and is accessible to the lay reader without any specialist knowledge. It explores the numerous concepts associated with offshore wind farm operation and maintenance with condition monitoring system, and vividly presents the the basics of wind energy, augmenting this with a large amount of valuable real wind farm case studies.
Modeling Wind Turbine John Wiley & Sons
First concise textbook on Large-Eddy Simulation, a very important method in scientific computing and engineering From the foreword to the third edition written by Charles Meneveau: "... this meticulously assembled and significantly enlarged description of the many aspects of LES will be a most welcome addition to the bookshelves of scientists and engineers in fluid mechanics, LES practitioners, and students of turbulence in general."
Modeling, Analysis and Enhancement of the performance of a Wind Driven DFIG During steady state and transient conditions Springer Science & Business Media
With increasing concern over climate change and the security of energy supplies, wind power is emerging as an important source of electrical energy throughout the world. Modern wind turbines use advanced power electronics to provide efficient generator control and to ensure compatible operation with the power system. Wind Energy Generation describes the fundamental principles and modelling of the electrical generator and power electronic systems used in large wind turbines. It also discusses how they interact with the power system and the influence of wind turbines on power system operation and stability. Key features: Includes a comprehensive account of power electronic equipment used in wind turbines and for their grid connection. Describes enabling technologies which facilitate the connection of large-scale onshore and offshore wind farms. Provides detailed modelling and control of wind turbine systems. Shows a number of simulations and case studies which explain the dynamic interaction between wind power and conventional generation.
Wind Energy Generation: Modelling and Control Springer
Recently, wind electrical power systems are getting a lot of attention since they are cost competitive, environmentally clean, and safe renewable power source as compared with the fossil fuel and nuclear power generation. A special type of induction generator, called a doubly fed induction generator (DFIG), is used extensively for high-power wind applications. They are used more and more in wind turbine applications due to the ease of controllability, the high energy efficiency, and the improved power quality.This research aims to develop a method of a field orientation scheme for control both, the active and the reactive powers of a DFIG that are driven by a wind turbine. Also, the dynamic model of the DFIG, driven by a wind turbine during grid faults, is analyzed and developed, using the method of symmetrical components. Finally, this study proposes a novel fault ride-through (FRT) capability with a suitable control strategy (i.e. the ability of the power system to remain connected to the grid during faults).
Modeling and Control for Wind Energy Generation John Wiley & Sons
This thesis investigates the use of blade-pitch control and real-time wind measurements to reduce the structural loads on the rotors and blades of wind turbines. The first part of the thesis studies the main similarities between the various classes of current blade-pitch control strategies, which have to date remained overlooked by mainstream literature. It also investigates the feasibility of an estimator design that extracts the turbine tower motion signal from the blade load measurements. In turn, the second part of the thesis proposes a novel model predictive control layer in the control architecture that enables an existing controller to incorporate the upcoming wind information and constraint-handling features. This thesis provides essential clarifications of and systematic design guidelines for these topics, which can benefit the design of wind turbines and, it is hoped, inspire the development of more innovative mechanical load-reduction solutions in the field of wind energy.
Power Conversion and Control of Wind Energy Systems Springer
In this thesis, a grid-connected wind-energy converter system including a matrix converter is proposed. The matrix converter, as a power electronic converter, is used to interface the induction generator with the grid and control the wind turbine shaft speed. At a given wind velocity, the mechanical power available from a wind turbine is a function of its shaft speed. Through the matrix converter, the terminal voltage and frequency of the induction generator is controlled, based on a constant V/f strategy, to adjust the turbine shaft speed and accordingly, control the active power injected into the grid to track maximum power for all wind velocities. The power factor at the

interface with the grid is also controlled by the matrix converter to either ensure purely active power injection into the grid for optimal utilization of the installed wind turbine capacity or assist in regulation of voltage at the point of connection. Furthermore, the reactive power requirements of the induction generator are satisfied by the matrix converter to avoid use of self-excitation capacitors. The thesis addresses two dynamic models: a comprehensive dynamic model for a matrix converter and an overall dynamical model for the proposed wind turbine system. The developed matrix converter dynamic model is valid for both steady-state and transient analyses, and includes all required functions, i.e., control of the output voltage, output frequency, and input displacement power factor. The model is in the qdo reference frame for the matrix converter input and output voltage and current fundamental components. The validity of this model is confirmed by comparing the results obtained from the developed model and a simplified fundamental-frequency equivalent circuit-based model. In developing the overall dynamic model of the proposed wind turbine system, individual models of the mechanical aerodynamic conversion, drive train, matrix converter, and squirrel-cage induction generator are developed and combined to enable steady-state and transient simulations of the overall system. In addition, the constraint constant V/f strategy is included in the final dynamic model. The model is intended to be useful for controller design purposes. The dynamic behavior of the model is investigated by simulating the response of the overall model to step changes in selected input variables. Moreover, a linearized model of the system is developed at a typical operating point, and stability, controllability, and observability of the system are investigated. Two control design methods are adopted for the design of the closed-loop controller: a state-feedback controller and an output feedback controller. The state-feedback controller is designed based on the Linear Quadratic method. An observer block is used to estimate the states in the state-feedback controller. Two other controllers based on transfer-function techniques and output feedback are developed for the wind turbine system. Finally, a maximum power point tracking method, referred to as mechanical speed-sensorless power signal feedback, is developed for the wind turbine system under study to control the matrix converter control variables in order to capture the maximum wind energy without measuring the wind velocity or the turbine shaft speed.

Wind Power Integration IET

The rapid growth of wind power and the implications of this on future power system planning, operation and control has become an even greater challenge in today's liberalised electricity market conditions. This essential book examines the main problems of wind power integration and guides the reader through a number of the most recent solutions based on current research and operational experience of wind power integration.

Non-steady Dynamics of Atmospheric Turbulence Interaction with Wind Turbine Loadings Through Blade-boundary-layer-resolved CFD. Routledge

An essential reference to the modeling techniques of wind turbine systems for the application of advanced control methods This book covers the modeling of wind power and application of modern control methods to the wind power control—specifically the models of type 3 and type 4 wind turbines. The modeling aspects will help readers to streamline the wind turbine and wind power plant modeling, and reduce the burden of power system simulations to investigate the impact of wind power on power systems. The use of modern control methods will help technology development, especially from the perspective of manufactures. Chapter coverage includes: status of wind power development, grid code requirements for wind power integration; modeling and control of doubly fed induction generator (DFIG) wind turbine generator (WTG); optimal control strategy for load reduction of full scale converter (FSC) WTG; clustering based WTG model linearization; adaptive control of wind turbines for maximum power point tracking (MPPT); distributed model predictive active power control of wind power plants and energy storage systems; model predictive voltage control of wind power plants; control of wind power plant clusters; and fault ride-through capability enhancement of VSC HVDC connected offshore wind power plants. Modeling and Modern Control of Wind Power also features tables, illustrations, case studies, and an appendix showing a selection of typical test systems and the code of adaptive and distributed model predictive control. Analyzes the developments in control methods for wind turbines (focusing on type 3 and type 4 wind turbines) Provides an overview of the latest changes in grid code requirements for wind power integration Reviews the operation characteristics of the FSC and DFIG WTG Presents production efficiency improvement of WTG under uncertainties and disturbances with adaptive control Deals with model predictive active and reactive power control of wind power plants Describes enhanced control of VSC HVDC connected offshore wind power plants Modeling and Modern Control of Wind Power is ideal for PhD students and researchers studying the field, but is also highly beneficial to engineers and transmission system operators (TSOs), wind turbine manufacturers, and consulting companies.