Wind Farm Modeling For Steady State And Dynamic Analysis

Model Predictive Control of Wind Energy Conversion Systems addresses the predicative control strategy that has emerged as a promising digital control tool within the field of power electronics, variable-speed motor drives, and energy conversion systems. The authors provide a comprehensive analysis on the model predictive control of power converters employed in a wide variety of variable-speed wind energy conversion systems (WECS). The contents of this book includes an overview of wind energy system configurations, power converters for variable-speed WECS, digital control techniques, MPC, modeling of power converters and wind generators for MPC design. Other topics include the mapping of continuous-time models to discrete-time models by various exact, approximate, and quasi-exact discretization methods, modeling and control of wind turbine grid-side two-level and multilevel voltage source converters. The authors also focus on the MPC of several power converter configurations for full variable-speed permanent magnet synchronous generator based WECS, squirrel-cage induction generator based WECS, and semi-variable-speed doubly fed induction generator based WECS. Furthermore, this book: Analyzes a wide variety of practical WECS, illustrating important concepts with case studies, simulations, and experimental results Provides a step-by-step design procedure for the development of predictive control schemes for various

WECS configurations Describes continuous- and discrete-time modeling of wind generators and power converters, weighting factor selection, discretization methods, and extrapolation techniques Presents useful material for other power electronic applications such as variable-speed motor drives, power quality conditioners, electric vehicles, photovoltaic energy systems, distributed generation, and high-voltage direct current transmission. Explores S-Function Builder programming in MATLAB environment to implement various MPC strategies through the companion website Reflecting the latest technologies in the field, Model Predictive Control of Wind Energy Conversion Systems is a valuable reference for academic researchers, practicing engineers, and other professionals. It can also be used as a textbook for graduate-level and advanced undergraduate courses.

Wind Power Integration provides a wide-ranging discussion on all major aspects of wind power integration into electricity supply systems. This second edition has been fully revised and updated to take account of the significant growth in wind power deployment in the past few years. New discussions have been added to describe developments in wind turbine generator technology and control, the network integration of wind power, innovative ways to integrate wind power when its generation potential exceeds 50% of demand, case studies on how forecasting errors have affected system operation, and an update on how the wind energy sector has fared in the marketplace. Topics covered include: the development of wind power technology and its worldwide deployment; wind power technology and the interaction of various wind turbine generator types with the utility network; and wind power forecasting and the challenges faced by wind energy in modern electricity markets. This comprehensive text requires no specialist knowledge. It will appeal to engineers from various disciplines looking for an overview of a technology that is providing a major impetus for sustainable electricity supply in the twenty-first century. Researchers, advanced postgraduate students in renewable energy and design engineers working with wind power devices will also benefit from this book.

Wind power is the fastest growing renewable energy and is promising to be the number one source of clean energy in the near future. Among various generators used to convert wind energy, the Doubly-Fed Induction Generator (DFIG) has attracted more attention due to its variable speed, higher energy capture efficiency and improved power quality. The DFIG system has back-to-back converters, one on the rotor side and one on the stator side. The two converters act as an optimal operation tracking interface between the generator and the grid or other loads. To achieve the desirable output power, field oriented control (FOC) or vector control is applied to both the rotor- and the stator-side converters. To achieve high efficiency in wind power systems, the maximum power point tracking (MPPT) of the variable-speed operation has attracted a lot of attention. Most MPPT methods either rely on wind speed measurement or on complicated estimations and online calculations. As a result, these methods are either expensive due to the need of wind speed sensors or suffer from inaccuracy due to variations of wind turbine system models. This dissertation proposes a novel self-tuning reference power MPPT curve. This reference power curve is simply updated by incrementally updating the curve coefficients. The method is robust and is independent of the wind turbine model. Also, regarding MPPT stability, this dissertation presents the steady state and dynamic analyses of this MPPT method. A single-pole transfer function that describes the effect of variations of wind speed on the rotor speed is obtained by applying small signal analysis on the turbine-rotor mechanical system. To verify the wind power control system and the proposed MPPT analysis, both simulation and experimental platforms are developed. First, the DFIG system, including a wind turbine, a generator, power electronic converters and power system grid are modeled. All of the control algorithms and operation modes are simulated. The active power is always controlled at maximum output while the reactive power is controlled to achieve a particular power factor or line voltage. Second, a complete DFIG wind power test bench including a wind turbine emulator is designed and built. The back-to-back converters are designed to control the DFIG. A Microchip dsPIC33 is used to control both turbine emulator and the converters. The utility grid integration is implemented with assistance of a Phase Locked Loop (PLL) and the rotor currents of DFIG are controlled to vary the operation point. Then, the proposed MPPT is simulated and incremental current control is implemented for optimal power tracking. The incremental change is not stopped until the optimal output power is reached. Also, both simulation and experimental results confirm the dynamic behavior of rotor speed predicted by the proposed transfer function. The real-time close-loop power control and Fault Ride Through (FRT) could be studied in the future based on the developed simulation and experimental systems. While the test bench is designed to flexibly fitting future wind research, more programming efforts are required to implement more complicated algorithms.

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.

Jens Fortmann describes the deduction of models for the grid integration of variable speed wind turbines and the reactive power control design of wind plants. The modeling part is intended as background to understand the theory, capabilities and limitations of the generic doubly fed generator and full converter wind turbine models described in the IEC 61400-27-1 and as 2nd generation WECC models that are used as standard library models of wind turbines for grid simulation software. Focus of the reactive power control part is a deduction of the origin and theory behind the reactive current requirements during faults found in almost all modern grid codes. Based on this analysis, the design of a reactive power control system for wind turbines and wind plants is deduced that can provide static and dynamic capabilities to ensure a stable voltage and reactive power control for future grids without remaining synchronous generation.

During the last two decades, increase in electricity demand and environmental concern resulted in fast growth of power production from renewable sources. Wind power is one of the most efficient alternatives. Due to rapid development of wind turbine technology and increasing size of wind farms, wind power plays a significant part in the power production in some countries. However, fundamental differences exist between conventional thermal, hydro, and nuclear generation and wind power, such as different generation systems and the difficulty in controlling the primary movement of a wind turbine, due to the wind and its random fluctuations. These differences are reflected in the specific interaction of wind turbines with the power system. This book addresses a wide variety of issues regarding the integration of wind farms in power systems. The book contains 14 chapters divided into three parts. The first part outlines aspects related to the impact of the wind power generation on the electric system. In the second part, alternatives to mitigate problems of the wind farm integration are presented. Finally, the third part covers issues of modeling and simulation of wind power system.

Renewable energies constitute excellent solutions to both the increase of energy consumption and environment problems. Among these energies, wind energy is very interesting. Wind energy is the subject of advanced research. In the development of wind turbine, the design of its different structures is very important. It will ensure: the robustness of the system, the energy efficiency, the optimal cost and the high reliability. The use of advanced control technology and new technology products allows bringing the wind energy conversion system in its optimal operating mode. Different strategies of control can be applied on generators, systems relating to blades, etc. in order to extract maximal power from the wind. The goal of this book is to present recent works on design, control and applications in wind energy conversion systems.

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.

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.

Wind energy's bestselling textbook- fully revised. This must-have second edition includes up-to-date data, diagrams, illustrations and thorough new material on: the fundamentals of wind turbine aerodynamics; wind turbine testing and modelling; wind turbine design standards; offshore wind energy; special purpose applications, such as energy storage and fuel production. Fifty additional homework problems and a new appendix on data processing make this comprehensive edition perfect for engineering students. This book offers a complete examination of one of the most promising sources of renewable energy and is a great introduction to this cross-disciplinary field for practising engineers. “provides a wealth of information and is an excellent reference book for people interested in the subject of wind energy.” (IEEE Power & Energy Magazine, November/December 2003) “deserves a place in the library of every university and college where renewable energy is taught.” (The International Journal of Electrical Engineering Education, Vol.41, No.2 April 2004) “a very comprehensive and well-organized treatment of the current status of wind power.” (Choice, Vol. 40, No. 4, December 2002)

The book is a collection of high-quality, peer-reviewed innovative research papers from the International Conference on Signals, Machines and Automation (SIGMA 2018) held at Netaji Subhas Institute of Technology (NSIT), Delhi, India. The conference offered researchers from academic and industry the opportunity to present their original work and exchange ideas, information, techniques and applications in the field of computational intelligence, artificial intelligence and machine intelligence. The book is divided into two volumes discussing a wide variety of industrial, engineering and scientific applications of the emerging techniques.

Grid Integration and Dynamic Impact of Wind Energy details the integration of wind energy resources to the electric grid worldwide. Authors Vijay Vittal and Raja Ayyanar include detailed coverage of the power converters and control used in interfacing electric machines and power converters used in wind generators, and extensive descriptions of power systems operation and control to accommodate large penetration of wind resources. Key concepts will be illustrated through extensive power electronics and power systems simulations using software like MATLAB, Simulink and

PLECS. The book addresses real world problems and solutions in the area of grid integration of wind resources, and will be a valuable resource for engineers and researchers working in renewable energy and power.

Wind power is currently considered as the fastest growing energy resource in the world. Technological advances and government subsidies have contributed in the rapid rise of Wind power systems. The Handbook on Wind Power Systems provides an overview on several aspects of wind power systems and is divided into four sections: optimization problems in wind power generation, grid integration of wind power systems, modeling, control and maintenance of wind facilities and innovative wind energy generation. The chapters are contributed by experts working on different aspects of wind energy generation and conversion.

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

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).

Wind Power Plant (WPP) and Wind Turbine (WT) modeling are becoming of key importance due to the relevant wind-generation impact on power systems. Wind integration into power systems must be carefully analyzed to forecast the effects on grid stability and reliability. Different agents, such as Transmission System Operators (TSOs) and Distribution System Operators (DSOs), focus on transient analyses. Wind turbine manufacturers, power system software developers, and technical consultants are also involved. WPP and WT dynamic models are often divided into two types: detailed and simplified. Detailed models are used for Electro-Magnetic Transient (EMT) simulations, providing both electrical and mechanical responses with high accuracy during short time intervals. Simplified models, also known as standard or generic models, are designed to give reliable responses, avoiding high computational resources. Simplified models are commonly used by TSOs and DSOs to carry out different transient stability studies, including loss of generation, switching of power lines or balanced faults, etc., Assessment and validation of such dynamic models is also a major issue due to the importance and difficulty of collecting real data. Solutions facing all these challenges, including the development, validation and application of WT and WPP models are presented in this Issue.

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.

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.

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.

Provides students with an understanding of the modeling and practice in power system stability analysis and control design, as well as the computational tools used by commercial vendors Bringing together wind, FACTS, HVDC, and several other modern elements, this book gives readers everything they need to know about power systems. It makes learning complex power system concepts, models, and dynamics simpler and more efficient while providing modern viewpoints of power system analysis. Power System Modeling, Computation, and Control provides students with a new and detailed analysis of voltage stability; a simple example illustrating the BCU method of transient stability analysis; and one of only a few derivations of the transient synchronous machine model. It offers a discussion on reactive power consumption of induction motors during start-up to illustrate the low-voltage phenomenon observed in urban load centers. Damping controller designs using power system stabilizer, HVDC systems, static var compensator, and thyristor-controlled series compensation are also examined. In addition, there are chapters covering flexible AC transmission Systems (FACTS)—including both thyristor and voltage-sourced converter technology—and wind turbine generation and modeling. Simplifies the learning of complex power system concepts, models, and dynamics Provides chapters on power flow solution, voltage stability, simulation methods, transient stability, small signal stability, synchronous machine models (steady-state and dynamic models), excitation systems, and power system stabilizer design Includes advanced analysis of voltage stability, voltage recovery during motor starts, FACTS and their operation, damping control design using various control equipment, wind turbine models, and control Contains numerous examples, tables, figures of block diagrams, MATLAB plots, and problems involving real systems Written by experienced educators whose previous books and papers are used extensively by the international scientific community Power System Modeling, Computation, and Control is an ideal textbook for graduate students of the subject, as well as for power system engineers and control design professionals.

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.

This book provides a platform for scientists and engineers to comprehend the technologies of solar wind hybrid renewable energy systems and their applications. It describes the thermodynamic analysis of wind energy systems, and advanced monitoring, modeling, simulation, and control of wind turbines. Based on recent hybrid technologies considering wind and solar energy systems, this book also covers modeling, design, and optimization of wind solar energy systems in conjunction with grid-connected distribution energy management systems comprising wind photovoltaic (PV) models. In addition, solar thermochemical fuel generation topology and evaluation of PV wind hybrid energy for a small island are also included in this book. Since energy storage plays a vital role in renewable energy systems, another salient part of this book addresses the methodology for sizing hybrid battery-backed power generation systems in off-grid connected locations. Furthermore, the book proposes solutions for sustainable rural development via passive solar housing schemes, and the impacts of renewable energies in general, considering social, economic, and environmental factors. Because this book proposes solutions based on recent challenges in the area of hybrid renewable technologies, it is hoped that it will serve as a useful reference to readers who would like to be acquainted with new strategies of control and advanced technology regarding wind solar hybrid systems

Simulation of Power System with Renewables provides details on the modelling and efficient implementation of MATLAB, particularly with a renewable energy driven power system. The book presents a step-by-step approach to modelling implementation, including all major components used in current power systems operation, giving the reader the opportunity to learn how to gather models for conventional generators, wind farms, solar plants and FACTS control devices. Users will find this to be a central resource for modelling, building and simulating renewable power systems, including discussions on its limitations, assumptions on the model, and the implementation and analysis of the system. Presents worked examples and equations in each chapter that address system limitations and flexibility Provides step-by-step guidance for building and simulating models with required data Contains case studies on a number of devices, including FACTS, and renewable generation Renewable Energy Systems: Modelling, Optimization and Control aims to cross-pollinate recent advances in the study of renewable energy control systems by bringing together diverse scientific breakthroughs on the modeling, control and optimization of renewable energy systems by leading researchers. The book brings together the most comprehensive collection of modeling, control theorems and optimization techniques to help solve many scientific issues for researchers in renewable energy and control engineering. Many multidisciplinary applications are discussed, including new fundamentals, modeling, analysis, design, realization and experimental results. The book also covers new circuits and systems to help researchers solve many nonlinear problems. This book fills the gaps between different interdisciplinary applications, ranging from mathematical concepts, modeling, and analysis, up to the realization and experimental work. Covers modeling, control theorems and optimization techniques which will solve many scientific issues for researchers in renewable energy Discusses many multidisciplinary applications with new fundamentals, modeling, analysis, design, realization and experimental results Includes new circuits and systems, helping researchers solve many nonlinear problems

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.
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.

This thesis describes the generic modeling of a Doubly-Fed Induction Generator (DFIG) based wind turbine. The model can also represent a wind plant with a group of similar wind turbines lumped together. The model is represented as a controlled current source which injects the current needed by the grid to supply the demanded real and reactive power. The DFIG theory is explained in detail as is the rationale for representing it by a regulated current source. The complete model is then developed in the time-domain and phasor domain by the interconnection of various sub-systems, the functions of which have been described in detail. The performance of the model is then tested for steady-state and dynamic operation. The model developed can be used for bulk power system studies and transient stability analysis of the transmission system. This thesis uses as its basis a report written for NREL (1).

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

The book presents the latest power conversion and control technology in modern wind energy systems. It has nine chapters, covering technology overview and market survey, electric generators and modeling, power converters and modulation techniques, wind turbine characteristics and configurations, and control schemes for fixed- and variable-speed wind energy systems. The book also provides in-depth steady-state and dynamic analysis of squirrel cage induction generator, doubly fed induction generator, and synchronous generator based wind energy systems. To illustrate the key concepts and help the reader tackle real-world issues, the book contains more than 30 case studies and 100 solved problems in addition to simulations and experiments. The book serves as a comprehensive reference for academic researchers and practicing engineers. It can also be used as a textbook for graduate students and final year undergraduate students.

The reduction of greenhouse gas emissions is a major governmental goal worldwide. The main target, hopefully by 2050, is to move away from fossil fuels in the electricity sector and then switch to clean power to fuel transportation, buildings and industry. This book discusses important issues in the expanding field of wind farm modeling and simulation as well as the optimization of hybrid and micro-grid systems. Section I deals with modeling and simulation of wind farms for efficient, reliable and cost-effective optimal solutions. Section II tackles the optimization of hybrid wind/PV and renewable energy-based smart micro-grid systems.

"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."--Publisher's website.

Measurement technologies and instrumentation have a multidisciplinary impact in the field of applied sciences. These engineering technologies are necessary in processing information required for renewable energy, biotechnology, power quality, and nanotechnology. Advanced Instrument Engineering: Measurement, Calibration, and Design presents theoretical and practical aspects on the activities concerning measurement technologies and instrumentation. This wide range of new ideas in the field of measurements and instrumentation is useful to researchers, scientists, practitioners, and technicians for their area of expertise.

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.

The concept of the smart grid promises the world an efficient and intelligent approach of managing energy production, transportation, and consumption by incorporating intelligence, efficiency, and optimality into the power grid. Both energy providers and consumers can take advantage of the convenience, reliability, and energy savings achieved by real-time and intelligent energy management. To this end, the current power grid is experiencing drastic changes and upgrades. For instance, more significant green energy resources such as wind power and solar power are being integrated into the power grid, and higher energy storage capacity is being installed in order to mitigate the intermittency issues brought about by the variable energy resources. At the same time, novel power electronics technologies and operating strategies are being invented and adopted. For instance, Flexible AC transmission systems and phasor measurement units are two promising technologies for improving the power system reliability and power quality. Demand side management will enable the customers to manage the power loads in an active fashion. As a result, modeling and control of modern power grids pose great challenges due to the adoption of new smart grid technologies. In this book, chapters regarding representative applications of smart grid technologies written by world-renowned experts are included, which explain in detail various innovative modeling and control methods.

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.

The increasing share of renewable energy resources in electricity generation requires reassessment of protection systems. This is due to the fact that renewables are often electronically coupled to the grid and their behavior under transient conditions is different from the behavior of power plants generating power using classical synchronous generators. The behavior of electronically coupled generators depends on the controllers of their converters, and in principle, their precise simulation under short-circuit conditions is possible using dynamic or transient tools which allow detailed modeling of controllers. However, protection and short-circuit software packages used by practicing engineers depend on steady-state solution engines built in phasor domain. The main objective of this thesis is to develop steady-state phasor models of wind and solar parks that provide their current contribution under steady-state short-circuit conditions. The steady-state models are developed for type-III and type-IV wind turbine generators. Negative sequence control and park controller options are also considered. The Type-IV model can also be used for modeling solar plants since both sources are connected via full converters. The steady-state models are validated using a detailed time-domain model that is developed in EMTP-RV software with the feedback of a leading European manufacturer of wind turbines. The phasor models take into account the behavior of converter conrollers and various control strategies associated with it. For large-scale wind parks connected to high voltage networks, the point of control is located at the point of interconnection of the park. The control strategies act on voltage, reactive power or power factor. In addition to these three control modes, a fault ride through mode is also available to support voltage during fault conditions. A current limiter protects the converters against overcurrent, and operates with P- or Q-priority. This limiter is indispensable but introduces a non-linear behavior. The phasor models take into account the natural negative sequence response of the wind turbine generator with two levels of precision if the controllers are not set to regulate negative sequence : simplified and detailed. Higher precision requires more details about the controller, such as the gains of the inner loop proportional-integral controller.

The wind energy has been known for a very long time. Historians estimate its age as over 3000 years old. The first written evidence indicates that windmills are heritage and history of Persia. Electrical energy from offshore wind is a relatively new source of electrical energy in contrast with conventional hydro and fossil fuel-based generation. Over the last decade, the installed capacity of wind farms has grown significantly across the globe.Regardless of technology used in the wind farm, injecting a significant amount of power into an existing power system has a huge impact on its control, stability, and resiliency. In particular, injection of the power into the transmission system concerns transfer capability, line congestion, reactive power support and synchronism in the grid. In addition, the uncertain and variable nature of wind power introduces more complexity in frequency control, unit commitment, market operation and protection. This research has developed a comprehensive methodology to identify transmission system upgrades that are needed to accommodate offshore wind projects. It also develops a series of techniques to determine operational impacts of offshore wind generation on reliability and resiliency under the steady state and dynamic operations of large-scale power systems including:Steady State Stability related issues in the system including voltage regulation and reactive power availability in the area as well as power transfer capability of the transmission system.Small Signal Stability related issues in the system as a result of variability of the offshore wind power including frequency stability by using frequency response and voltage stability by using frequency domain analysis to identify the dominant voltage modes.Large Signal Stability related issues in the system as a result of operation of variable offshore wind power including rotor angle stability, frequency stability, voltage stability for long term and short term faults.This study used a simulation model of the US Eastern Interconnection as the test system and focused on the integration of a 1000MW offshore wind farm operating in Lake Erie into FirstEnergy/PJM service territory as a case study.The findings of this research provide recommendations on offshore wind integration scenarios, the locations of points of interconnection, wind profile modeling and simulation, and computational methods to quantify performance, along with operating changes and equipment upgrades needed to mitigate system performance issues introduced by an offshore wind project.