

Wind Power Generation and Wind Turbine Design

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Wind Power Generation and Wind Turbine Design

Edited by:

Wei Tong

Kollmorgen Corp., USA

WITPRESS Southampton, Boston



Edited by: **Wei Tong**, *Kollmorgen Corp., USA*

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Preface

Along with the fast rising energy demand in the 21st century and the growing recognition of global warming and environmental pollution, energy supply has become an integral and cross-cutting element of economies of many countries. To respond to the climate and energy challenges, more and more countries have prioritized renewable and sustainable energy sources such as wind, solar, hydropower, biomass, geothermal, etc., as the replacements for fossil fuels.

Wind is a clean, inexhaustible, and an environmentally friendly energy source that can provide an alternative to fossil fuels to help improve air quality, reduce greenhouse gases and diversify the global electricity supply. Wind power is the fastest-growing alternative energy segment on a percentage basis with capacity doubling every three years. Today, wind power is flourishing in Europe, North America, and some developing countries such as China and India. In 2009, over 37 GW of new wind capacity were installed all over the world, bringing the total wind capacity to 158 GW. It is believed that wind power will play a more active role as the world moves towards a sustainable energy in the next several decades.

The object of this book is to provide engineers and researchers in the wind power industry, national laboratories, and universities with comprehensive, up-to-date, and advanced design techniques and practical approaches. The topics addressed in this book involve the major concerns in wind power generation and wind turbine design. An attempt has been made to include more recent developments in innovative wind technologies, particularly from large wind turbine OEMs. This book is a useful and timely contribution to the wind energy community as a resource for engineers and researchers. It is also suitable to serve as a textbook for a one- or two-semester course at the graduate or undergraduate levels, with the use of all or partial chapters.

To assist readers in developing an appreciation of wind energy and modern wind turbines, this book is organized into four parts. Part I consists of five chapters,

covering the basics of wind power generation. Chapter 1 provides overviews of the history of wind energy applications, fundamentals of wind energy and basic knowledge of modern wind turbines. Chapter 2 describes how to make wind resource assessment, which is the most important step for determining initial feasibility in a wind project. The assessment may pass through several stages such as initial site identification, detailed site characterizations, site suitability, and energy yield and losses. As a necessary tool for modeling the loads of wind turbines and designing rotor blades, the detail review of aerodynamics, including analytical theories and experiments, are presented in Chapter 3. Chapter 4 provides an overview of the frontline research on structural dynamics of wind turbines, aiming at assessing the integrity and reliability of the complete construction against varying external loading over the targeted lifetime. Chapter 5 discusses the issues related to wind turbine acoustics, which remains one of the challenges facing the wind power industry today.

Part 2 comprises seven chapters, addressing design techniques and developments of various wind turbines. One of the remarkable trends in the wind power industry is that the size and power output from an individual wind turbines have been continuously increasing since 1980s. As the mainstream of the wind power market, multi-megawatts wind turbines today are extensively built in wind farms all over the world. Chapter 6 presents the detail designing methodologies, techniques, and processes of these large wind turbines. While larger wind turbines play a critical role in on-grid wind power generation, small wind turbines are widely used in residential houses, hybrid systems, and other individual remote applications, either on-grid or off-grid, as described in Chapter 7. Chapter 8 summarises the principles of operation and the historical development of the main types of vertical-axis wind turbines. Due to some significant advantages, vertical-axis turbines will coexist with horizontal-axis turbines for a long time. The innovative turbine techniques are addressed in Chapter 9 for the direct drive superconducting wind generators and in Chapter 10 for the tandem wind rotors. To fully utilize the wind resource on the earth, offshore wind turbine techniques have been remarkably developed since the mid of 1980s. Chapter 11 highlights the challenges for the offshore wind industry, irrespective of geographical locations. To shed new light on small wind turbines, Chapter 12 focuses on updated state-of-the-art technologies, delivering advanced small wind turbines to the global wind market with lower cost and higher reliability.

Part 3 contains five chapters, involving designs and analyses of primary wind turbine components. As one of the most key components in a wind turbine, the rotor blades strongly impact the turbine performance and efficiency. As shown in Chapter 13, the structural design of turbine blades is a complicated process that requires know-how of materials, modeling and testing methods. In Chapter 14, the implementation of the smart rotor concept is addressed, in which the aerodynamics along the blade is controlled and the dynamic loads and modes are dampened. Chapter 15 explains the gear design criteria and offers solutions to the various gear design problems. Chapter 16 involves the design and analysis of wind turbine towers. In pace with the increases in rotor diameter and tower height for large wind turbines, it becomes more important to ensure the serviceability and survivability of towers.

For offshore wind turbines, the design of support structures is described in Chapter 17. In this chapter, the extensive overviews of the different foundation types, as well as their fabrications and installations, are provided.

Part 4 includes four chapters, dealing with other important issues in wind power generation. The subject of Chapter 18 is to describe approaches to determine the wind power curves, which are used to estimate the power performing characteristics of wind turbines. Cooling of wind turbines is another challenge for the turbine designers because it strongly impacts on the turbine performance. Various cooling techniques for wind turbines are reviewed and evaluated in Chapter 19. As a complement of Chapter 5, Chapter 20 focuses on engineering approaches in noise measurements and noise abatement methods. In Chapter 21, almost all up-to-the date available wind energy storage techniques are reviewed and analyzed, in view of their applications, costs, advantages, disadvantages, and prospects.

To comprehensively reflect the wind technology developments and the tendencies in wind power generation all over the world, the contributors of the book are engaged in industries, national laboratories and universities at Australia, China, Denmark, Germany, Greece, Ireland, Japan, Sweden, The Netherlands, UK, and USA.

I gratefully acknowledge all contributors for their efforts and dedications in preparing their chapters. The book has benefited from a large number of reviewers all over the world. With their constructive comments and advice, the quality of the book has been greatly enhanced. Finally, special thanks go to Isabelle Strafford and Elizabeth Cherry at WIT Press for their efficient work for publishing this book.

Wei Tong

Radford, Virginia, USA, 2010

List of Contributors

Stephan Barth

ForWind – Center for Wind Energy Research of
the Universities of Oldenburg, Bremen and
Hannover
D-26129 Oldenburg
Germany
Email: stephan.barth@forwind.de

Biswajit Basu

School of Engineering
Trinity College Dublin
Dublin 2
Ireland
Email: basub@tcd.ie

Harald Bersee

Faculty of Aerospace Engineering
Delft University of Technology
Kluyverweg 1
2628 CN Delft
The Netherlands
Email: H.E.N.Bersee@tudelft.nl

Sumit Bose

Global Research Center
General Electric Company
Niskayuna, NY 12309
USA
Email: bose@ge.com

Kim Branner

Wind Energy Division
Risø National Laboratory for Sustainable Energy
DK-4000 Roskilde
Denmark
Email: kibr@risoe.dtu.dk

Povl Brøndsted

Materials Research Division
Risø National Laboratory for Sustainable Energy
DK-4000 Roskilde
Denmark
Email: pobr@risoe.dtu.dk

Denis Noel Buckley

The Charles Parsons Initiative
Department of Physics
University of Limerick
Castletroy, Limerick
Ireland
Email: noel.buckley@ul.ie

David Connolly

The Charles Parsons Initiative
Department of Physics
University of Limerick
Castletroy, Limerick
Ireland
Email: david.connolly@ul.ie

Paul Cooper

School of Mechanical, Materials and
Mechatronic Engineering
University of Wollongong
Wollongong, NSW 2522
Australia
Email: pcooper@uow.edu.au

Niels F. B. Diepeveen

Department of Offshore Engineering
Delft University of Technology
2628 CN Delft
The Netherlands
Email: n.f.b.diepeveen@tudelft.nl

Laszlo Fuchs

Division of Fluid Mechanics
Lund University
S-22100 Lund
Sweden
Email: Laszlo.Fuchs@energy.lth.se

Ray Hicks

Ray Hicks Ltd
Llangammarch Wells, Powys
LD4 4BS
UK
Email: raymondhicks@btinternet.com

John W. Holmes

Materials Research Division
Risø National Laboratory for Sustainable Energy
DK-4000 Roskilde
Denmark
Email: jwho@risoe.dtu.dk

Anton W. Hulskamp

Faculty of Aerospace Engineering
Delft University of Technology
Kluyverweg 1
2629 HS Delft
The Netherlands
Email: A.W.Hulskamp@tudelft.nl

Yanlong Jiang

Department of Man-Machine and Environment
Engineering
Nanjing University of Aeronautics and
Astronautics
Nanjing 210016
China
Email: jiang-yanlong@nuaa.edu.cn

Toshiaki Kanemoto

Department of Mechanical and Control
Engineering
Kyushu Institute of Technology
1-1 Sensui, Tobata,
Kitakyushu, Fukuoka, 804-8550
Japan
Email: kanemoto@mech.kyutech.ac.jp

Koichi Kubo

Graduate School of Engineering
Kyushu Institute of Technology
1-1 Sensui, Tobata,
Kitakyushu, Fukuoka, 804-8550
Japan
Email: h584104k@tobata.isc.kyutech.ac.jp

Wiebke Langreder

Wind&Site, Suzlon Energy A/S
DK 8000 Århus C
Denmark
Email: wiebke.langreder@suzlon.com

Martin John Leahy

The Charles Parsons Initiative
Department of Physics
University of Limerick
Castletroy, Limerick
Ireland
Email: martin.leahy@ul.ie

Clive Lewis

Converteam UK Ltd
Rugby, Warwickshire
CV21 1BU
UK
Email: clive.lewis@converteam.com

Hikary Matsumiya

Hikarywind Lab., Ltd
5-23-4 Seijo, Setagaya-ku
Tokyo 157-0066
Japan
Email: Hikaruwind@aol.com

Patrick Milan

ForWind – Center for Wind Energy Research of
the Universities of Oldenburg, Bremen and
Hannover
D-26129 Oldenburg
Germany
Email: patrick.milan@uni-oldenburg.de

Panagiota Pantazopoulou

BRE
Bucknalls Lane
Watford, Hertfordshire WD25 9XX
UK
Email: PantazopoulouP@bre.co.uk

Joachim Peinke

ForWind – Center for Wind Energy Research of
the Universities of Oldenburg, Bremen and
Hannover
D-26129 Oldenburg
Germany
Email: joachim.peinke@forwind.de

David J. Cerda Salzmann

Department of Offshore Engineering
Delft University of Technology
2628 CN Delft
The Netherlands
Email: d.j.cerdasalzmnn@tudelft.nl

Alois P. Schaffarczyk

Center of Excellence for Wind Energy
(CEWind)
Kiel University of Applied Sciences
Grenzstrasse 3
D-24149 Kiel
Germany
Email: alois.schaffarczyk@fh-kiel.de

Bent F. Sørensen

Materials Research Division
Risø National Laboratory for Sustainable Energy
DK-4000 Roskilde
Denmark
Email: bent.soerensen@risoe.dk

Lawrence S. Staudt

Center for Renewable Energy
Dundalk Institute of Technology
Dundalk, County Louth
Ireland
Email: Larry.Staudt@dkit.ie

Robert-Zoltan Szasz

Department of Energy Sciences
Lund University
P.O. Box 118
221 00 Lund
Sweden
Email: Robert-Zoltan.Szasz@energy.lth.se

Jan van der Tempel

Department of Offshore Engineering
Delft University of Technology
2628 CN Delft
The Netherlands
Email: j.vandertempel@tudelft.nl

Wei Tong

Kollmorgen Corp.
201 W. Rock Road
Radford, VA 24141
USA
Email: wei.tong@kollmorgen.com

Spyros G. Voutsinas

School of Mechanical Engineering
National Technical University of Athens
15780 Zografou
Athens, Greece
Email: spyros@fluid.mech.ntua.gr

W. E. de Vries

Department of Offshore Engineering
Delft University of Technology
2628 CN Delft
The Netherlands
Email: w.e.devries@tudelft.nl

Matthias Wächter

ForWind – Center for Wind Energy Research of
the Universities of Oldenburg, Bremen and
Hannover
D-26129 Oldenburg
Germany
Email: matthias.waechter@uni-oldenburg.de

Lawrence D. Willey

Energy Wind
General Electric Company
300 Garlington Road
Greenville, SC 29602
USA
Email: lawrence.willey@ge.com
lwilley@clipperwind.com (present)

Danian Zheng

Infrastructure Energy
General Electric Company
300 Garlington Road
Greenville, SC 29615
USA
Email: danian.zheng@ge.com