OFFSHORE WIND ENERGY

Many countries have plans to expand wind energy to meet CO_2 emissions targets. Lack of available land area and the need for good and stable wind conditions have stimulated the development of offshore wind generation technology, which allows for the development of larger turbines. The offshore environment, however, involves new challenges related to the design, installation, operation and maintenance of the turbines.

Based on graduate-level courses taught by the author, this book focuses on the opportunities and challenges related to offshore wind turbines. It introduces the offshore environment, including wind and wave dynamics, before discussing the aerodynamics of wind turbines, hydrodynamic loading, marine operations and wind farm layout. Featuring examples that demonstrate practical application of the topics covered and exercises to consolidate student understanding, this is an indispensable reference text for advanced students and researchers of environmental science and engineering and for industry professionals working in the wind energy sector.

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Environmental Conditions and Dynamics of Fixed and Floating Turbines

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Preface

The inspiration to write this book came from the recent focus on offshore wind energy as part of the solution to convert the global energy supply from fossil fuel to renewables. Several important actors, e.g., the International Energy Agency, have pointed toward the potential large contribution from offshore wind energy in the future energy supply. However, moving wind turbines into the ocean and scaling up the turbine sizes adds new challenges compared to traditional wind turbines on land. To realize the offshore wind energy potential, increased competence in a wide range of professional disciplines is thus required.

In my personal professional carrier, I have dealt with topics such as ship hydrodynamics, propeller design, model and full-scale testing, wave loads, structural loads and marine operations, as well as analyzing and testing fixed and floating wind turbines. I have realized that the design and operation of offshore wind turbines relies upon an understanding of a wide range of scientific and engineering disciplines. Even if no individual involved in planning, design and operation can master all the required disciplines in detail, some basic insight is needed to secure precise and efficient communication between specialists. My hope is that this book can contribute to this. The book covers a wide range of topics but does not cover every topic in great detail. For that purpose, references are given to specialized literature.

Most of the material included in this book is based upon material used in lecturing graduate-level courses in marine operations at the Norwegian University of Science and Technology (NTNU) (Nielsen, 2007) and courses in offshore wind energy at the University of Bergen (UiB). The material also builds upon methods developed and published during my carrier in industry. Having the privilege to lead the research project developing the world's first multimegawatt floating wind turbine, Hywind Demo (installed offshore of Norway in 2009), gave me a unique opportunity to experience the importance of cross-disciplinary insight. Also, having the privilege to head the Bergen Offshore Wind Centre (BOW) at UiB from its inauguration in 2018

has given me the opportunity to further explore and learn the importance of cross-disciplinary work. At BOW, e.g., noise from wind turbines, the erosion of turbine blades, impacts on the marine environment, societal perspectives and legal issues have been covered. These are all important issues for the successful development of offshore wind energy, but are not covered in this book.

My hope is that this book can be used in graduate as well as continued education within offshore wind energy, giving a broad overview of key topics related to the environmental conditions and dynamic response of offshore wind turbines. For deeper insight into, e.g., meteorology, aerodynamics and marine hydrodynamics, specialized courses and literature should be consulted.

This book could not have been written without the encouragement and inspiration of several persons, among them: Christina Aabo of Aabo Energy and a member of the Scientific Advisory Board (SAC) of BOW; Jan-Fredrik Stadaas of Equinor and a member of SAC; Adjunct Associate Professor Marte Godvik, UiB and Equinor; Professor Henrik Bredmose, DTU and member of SAC; and Dr. Kristin Guldbrandsen Frøysa, Energy Director at UiB. Many individuals have also contributed with comments and advice on specific chapters, among them several present and former colleagues: Adjunct Professor Bjørn Skaare, University of Stavanger and Equinor; Dr. Herbjørn Haslum, Equinor; Dr. Rolf Børresen; Adjunct Professor Birgitte Rugaard Furevik, UiB and Norwegian Meteorological Institute; Associate Professor Mostafa Bakhoday Paskyabi, UiB; Professor Cristian Guillermo Gebhardt, UiB; Professor Joachim Reuder, UiB; Associate Professor Etienne Cheynet, UiB; Dr. Astrid Nybø, Odfjell Offshore Wind; and Dr. Ida Marie Solbrekke, NORCE. Thanks to all for their contributions! Thanks also to Anna Therese Klingstedt for creating the illustrations of floating wind turbines.