

Sathyajith Mathew

Wind Energy

Fundamentals, Resource Analysis and Economics

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Resource Analysis
and Economics

with 137 Figures and 31 Tables

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Who has gathered the wind in his fists?

.....**Proverbs 30:4**

*Dedicated to my parents,
wife Geeta Susan and kids Manuel & Ann*

Preface

Growing energy demand and environmental consciousness have re-evoked human interest in wind energy. As a result, wind is the fastest growing energy source in the world today. Policy frame works and action plans have already been formulated at various corners for meeting at least 20 per cent of the global energy demand with new-renewables by 2010, among which wind is going to be the major player.

In view of the rapid growth of wind industry, Universities, all around the world, have given due emphasis to wind energy technology in their undergraduate and graduate curriculum. These academic programmes attract students from diversified backgrounds, ranging from social science to engineering and technology. Fundamentals of wind energy conversion, which is discussed in the preliminary chapters of this book, have these students as the target group. Advanced resource analysis tools derived and applied are beneficial to academics and researchers working in this area. The Wind Energy Resource Analysis (WERA) software, provided with the book, is an effective tool for wind energy practitioners for assessing the energy potential and simulating turbine performance at prospective sites.

The introductory chapter narrates the historic development of wind energy technology along with its present status and future prospects. This is followed by Chapter 2, which presents the basic principles of wind energy conversion. Descriptions on different types of wind machines and their performances are briefed here. Basics of wind rotor aerodynamics and its application in the turbine design are also presented in this chapter.

The third chapter is devoted to the methods of measurement and analysis of wind spectra for energy use. Statistical methods for wind energy analysis are introduced here. These are further extended for developing models for estimating the wind energy potential of a prospective site.

Constructional features of various systems and sub-systems of a Wind Energy Conversion System (WECS) are described in Chapter 4. Along with wind electric generators, wind powered water pumping systems are also considered. Features of wind farms, both onshore and offshore, are also discussed in this chapter.

Chapter 5 deals with performance models of WECS. Tools to simulate the field performance of wind powered generators and water pumps are presented in this section. Optimal matching of WECS with the site is also discussed.

Sixth chapter is devoted to the environmental aspects of wind energy conversion. While highlighting the environment related merits of wind energy, the recent

concerns over avian issues, visual impacts, noise etc. are not overlooked. A life cycle based approach is adopted for these discussions.

Economics of wind energy conversion is analysed in Chapter 7, following the present worth method. Factors affecting the costs and benefits of wind generated electricity are discussed and indices for economic appraisal are evolved.

Wind Energy Resource Analysis (WERA) software, which comes along with the book, is beneficial to readers who are not familiar with the numerical techniques applied in wind resource analysis. Illustrative examples included in all the chapters compliment the concepts presented in the text.

Subjects presented in this book are primarily derived from my experiences in teaching undergraduate and graduate engineering students. Research and field experiences on WECS have also helped me in formulating the materials presented. Further, serving as a resource person for various wind energy training programmes has also helped me in adopting a multi-disciplinary approach, which is essential for tackling a subject like wind energy. Hence, I would like to thank my students for their contribution.

Compiling information from various sources is essential for developing a book of this nature. I thank the authors of research papers and reports, which are referred in various chapters of this book. Several industries and organizations have supported me by providing information and materials which were essential for this project. Special thanks are due to Hawaiian Electric Company, Renewable Energy Systems Ltd, THALES instruments GmbH, Vaisala Oyj, Siemens Wind Power A/S, ReSoft, and Wikipedia, on this account.

I am fortunate to have the wholehearted support from my professors and colleagues for this project. Let me thank Prof. K.I. Koshy, Prof. C.P. Muhammad and Prof. Jippu Jacob for perusing the manuscript. Contribution of Prof. Anilkumar V and Dr. Damodar Rao in developing WERA is thankfully acknowledged. Thanks are also due to Prof. John D Burton, Prof. K.P Pandey, Prof. Ashok Alex Philip, Prof. Vishnu B, Dr. Dhalin D and Er. Nisha T.V, for their helps at various stages of this work.

As 'to err is human', suggestions for improving the content of this book in future are most welcome.

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