

WIND ENERGY DESIGN

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Forward

This book is intended to be a text for a senior-level Engineering course dealing with the conceptual design of a wind energy system. It is based on our experience in teaching “capstone” design classes in Aerospace Engineering for the past 20 years. The emphasis here being towards wind energy. The approach is to demonstrate how the theoretical aspects, drawn from topics on rotor aerodynamics, light-weight structures, control, acoustics, energy storage, and economics, can be applied to produce a new conceptual wind energy design. The book cites theoretical expressions where ever possible, but also stresses the interplay of different aspects of the design which often require compromises. As necessary, it draws on historical information to provide needed input parameters, especially at an early stage of the design process. In addition, historical wind energy systems are used to provide checks on design elements to determine if they deviate too far from historical norms.

The process of the conceptual design of an wind wnergy system is broken into 10 steps. These are covered in Chapters 4 to 11. The book stresses the use of interactive computational approaches for iterative and/or repetitive calculations. Sample calculations covering each step of the design are provided for each chapter, except 1 and 12. A case study of a wind energy system based on a 1.5 MW horizontal wind turbine runs through each chapter. Each part of this case study that relates to the particular chapter topic is discussed at the end of each chapter. In addition, there are individual problems at the end of each chapter in which the students are asked to document different degrees of dependence of the design characteristics on changing input conditions. Some of these problems are “open ended” and require interpretation and discussion.

The learning objective are (1) to understand how to characterize the properties of the wind resource from which the power is to be extracted, (2) to understand how to predict the performance of a horizontal axis wind turbine using Blade Element Momentum (BEM) theory, (3) to understand the blade design features and aerodynamics that yield an efficient rotor, (4) to understand how various rotor design considerations influence the wind turbine performance, (5) to understand aspects of active control to enhance turbine performance, and (6) to understand the economic issues related to wind turbines and wind farms.

The book can be used in either of two ways. First, it can be used to develop a complete conceptual design of a new wind energy system. This is the way that we personally teach this material. Starting at the beginning, the students develop

a complete design (similar to the case study) in a step-by-step fashion. This is accomplished over one semester (15 weeks).

The second use of the book is to consider individual aspects of a wind energy system without developing a complete design. This approach makes the best use of the problem sets at the end of each chapter. The effect of different input parameters can be easily investigated, and optimums can be sought. We know of instructors who prefer this approach.

The following is a list of chapters.

Chapter 1: Introduction

Chapter 2: Atmospheric Boundary Layer and Wind Characteristics

Chapter 3: Introduction to Aerodynamics

Chapter 4: Aerodynamic Performance of a Wind Turbine Rotor

Chapter 5: Wind Turbine Control

Chapter 6: Structural Design

Chapter 7: Wind Farms

Chapter 8: Wind Turbine Acoustics

Chapter 9: Wind Energy Storage

Chapter 10: Wind Energy Economics

Chapter 11: Design Summary and Trade Study

Chapter 12: New Concepts

For a complete conceptual design, the chapters are intended to be followed in chronological order. A conscious attempt has been made to include within each chapter, all of the supplementary material that is needed to develop that aspect of the design. This minimizes the need to search for formulas or graphs in other chapters or references.

The Chapter 11 summarizes the case study which runs throughout the text, and discusses the role of a Trade Study on a complete design. This is illustrated with the case study design, and in the problems at the end of the chapter. Chapter 12 presents new concepts for wind energy. Some of these are topical which leads to a discussion on the motivation and practicality of the concepts.

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