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, lightweight 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 energy 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.
Contents

1 Introduction .................................................................................. 9
  1.1 History of Wind Energy ......................................................... 9
    1.1.1 Modern Era of Wind Energy ......................................... 22

2 Wind Regimes .............................................................................. 33
  2.1 Origin of Wind ....................................................................... 33
  2.2 Atmospheric Boundary Layer ............................................... 34
  2.3 Temporal Statistics .............................................................. 38
  2.4 Wind Speed Probability ......................................................... 39
  2.5 Statistical Models ............................................................... 42
    2.5.1 Weibull Distribution ..................................................... 42
    2.5.2 Methods for Weibull model fits. ..................................... 46
    2.5.3 Rayleigh Distribution .................................................... 51
  2.6 Energy Estimation of Wind Regimes ..................................... 52
    2.6.1 Rayleigh-based Energy Estimation Approach ................. 55
  2.7 Wind Condition Measurement ............................................. 59
    2.7.1 Wind Speed Anemometers ........................................... 59

3 Introduction to Aerodynamics .................................................. 65

4 Aerodynamic Performance ....................................................... 67
  4.1 Momentum Theory ............................................................ 67
  4.2 Momentum Theory with Wake Rotation ............................. 79
  4.3 Blade Element Momentum (BEM) Theory ......................... 84
  4.4 Prandtl’s Tip Loss Factor .................................................... 89
  4.5 Solution of the BEM Equations .......................................... 91
    4.5.1 Example BEM Equation Solution ................................. 92
5 Wind Turbine Control 103
5.1 Aerodynamic Torque Control ........................................ 106
5.1.1 Electrical Torque Control ........................................ 107
5.2 Wind Turbine Operation Strategy ................................. 109
5.2.1 Fixed Speed Designs .............................................. 109
5.2.2 Variable Speed Designs ............................................ 110
5.2.3 Variable Speed Adaptive Torque Control .................... 112
5.3 Axial Induction Control ............................................. 113

6 Structural Design 127
6.1 Rotor Response to Loads ........................................... 133
6.2 Rotor Vibration Modes ............................................. 139
6.3 Design for Extreme Conditions ................................... 143

7 Wind Farms 147
7.0.1 Wind Turbine Wake Effects ................................. 148
7.0.2 Wind Farm Design Optimization .............................. 153

8 Wind Turbine Acoustics 155
8.1 Acoustics Fundamentals .......................................... 156
8.2 Sound Pressure Measurement and Weighting .................. 158
8.3 dB Math .......................................................... 160
8.4 Low Frequency and Infrasound ................................ 161
8.5 Wind Turbine Sound Sources ................................... 162
8.6 Sound Propagation ................................................. 167
8.7 Background Sound ................................................. 169
8.8 Noise Standards .................................................. 170

9 Wind Energy Storage 173
9.1 Electro-chemical Energy Storage .............................. 174
9.1.1 Lead-acid Batteries .............................................. 174
9.1.2 Nickel-based Batteries ......................................... 176
9.1.3 Lithium-based Batteries ....................................... 177
9.1.4 Additional Electro-chemical Storage Technologies ...... 177
9.1.5 Sodium Sulfur Batteries ....................................... 178
9.1.6 Redox Flow Battery ............................................ 179
9.1.7 Metal-air Battery ............................................... 179
9.2 Supercapacitor Storage .......................................... 180
9.3 Hydrogen Storage ........................................ 182
9.4 Mechanical Energy Storage Systems .................... 184
  9.4.1 Pumped Storage Hydroelectricity ................... 184
  9.4.2 Compressed Air Storage ......................... 185
  9.4.3 Flywheel Storage ................................. 188
9.5 CAES Case Study ....................................... 190
  9.5.1 Cost Function .................................. 194
  9.5.2 Net Benefit ..................................... 197
9.6 Battery Case Study ................................... 198
9.7 Hydro-electric Storage Case Study ...................... 200
9.8 Buoyant Hydraulic Energy Storage Case Study ........ 201

10 Economics .............................................. 205
  10.1 Cost of Energy, COE ................................. 206
  10.2 Component Estimate Formulas ..................... 208
  10.3 Example Cost Breakdown ......................... 219
  10.4 Summary .......................................... 221

11 Design Summary and Trade Study ........................ 223

12 New Concepts .......................................... 225
  12.1 Vertical Axis Wind Turbine ......................... 225
  12.2 Wind Focusing Concepts ............................ 228
  12.3 Bladeless Wind Turbine Concepts ................... 233
    12.3.1 Airborne Wind Turbine Concepts ............... 233
  12.4 Other Concepts .................................... 237