Preface

Actual strategies for sustainable energy development have as prior objective the gradual replacement of fossil-fuel-based energy sources by renewable energy ones. Among the clean energy sources, wind energy conversion systems currently carry significant weight in many developed countries. Following continual efforts of the international research community, a mature wind energy conversion technology is now available to sustain the rapid dynamics of concerned investment programs.

The main problem regarding wind power systems is the major discrepancy between the irregular character of the primary source (wind speed is a random, strongly non-stationary process, with turbulence and extreme variations) and the exigent demands regarding the electrical energy quality: reactive power, harmonics, flicker, *etc*. Thus, wind energy conversion within the parameters imposed by the energy market and by technical standards is not possible without the essential contribution of automatic control.

The stochastic nature of the primary energy source represents a risk factor for the viability of the mechanical structure. The literature concerned emphasises the importance of the reliability criterion, sometimes more important than energy conversion efficiency (*e.g.*, in the case of off-shore farms), in assessing global economic efficiency. This aspect must be taken into account in control strategies.

Many research works deal with wind power systems control, aiming at optimising the energetic conversion, interfacing wind turbines to the grid and reducing the fatigue load of the mechanical structure. Meanwhile, the gap between the development of advanced control algorithms and their effective use in most of the practical engineering domain is widely recognized. Much work has been and continues to be done, especially by the research community, in order to bridge this gap and ease the technology transfer in control engineering.

This book is aimed at presenting a point of view on the wind power generation optimal control issues, covering a large segment of industrial wind power applications. Its main idea is to propose the use of a set of optimization criteria which comply with a comprehensive set of requirements, including the energy conversion efficiency, mechanical reliability, as well as quality of the energy provided. This idea opens the perspective toward a multi-purpose global control approach.

A series of control techniques are analyzed, assessed and compared, starting from the classical ones, like PI control, maximum power point strategies, LQG optimal control techniques, and continuing with some modern ones: sliding-mode techniques, feedback linearization control and robust control. The discussion is aimed at identifying the benefits of dynamic optimization approaches to wind power systems. The main results are presented along with illustration by case studies and MATLAB®/Simulink® simulation assessment. The corresponding software programmes and block diagrams are included on the back-of-book software material. For some of the case studies presented real-time simulation results are also available.

The discourse of this book concludes by stressing the point on the possibility of designing WECS control laws based upon the frequency separation principle. The idea behind this is simple. First, one must define the set of quality demands the control law must comply with. Then one seeks to split this set into contradictory pairs, for each of them a component of the control law being separately synthesized. Finally, these components are summed to yield the total control input. This approach is possible because the different WECS dynamic properties usually involved in the imposed quality requirements are exhibited in disjointed frequency ranges.

Offering a thorough description of wind energy conversion systems – principles, functionality, operation modes, control goals and modelling – this book is mainly addressed to researchers with a control background wishing either to approach or to go deeper in their study of wind energy systems. It is also intended to be a guide for control engineers, researchers and graduate students working in the field in learning and applying systematic optimization procedures to wind power systems.

The book is organised in seven chapters preceded by a glossary and followed by a concluding chapter, three appendices, a list of pertinent references and an index.

Chapter 1 realises an introduction about the wind energy resource and systems. Chapter 2 presents a systemic analysis of the main parts of a wind energy conversion system and introduces the associated control objectives. The modelling development needed for control purposes is presented in the Chapter 3. Chapter 4 is dedicated to explaining the fundamentals of the wind turbine control systems. In Chapter 5 some powerful control methods for energy conversion maximization are presented, each of which is illustrated by a case study. Chapter 6 deals with mixed optimization criteria and introduces the frequency separation principle in the optimal control of the wind energy systems, whose effectiveness is suggested by two case studies. Chapter 7 is focused on using the hardware-in-the-loop simulation philosophy for building development systems that experimentally validate the wind energy systems control laws. A case study is presented to illustrate the proposed methodology. Chapter 8 discusses general conclusions and suggestions for future development of WECS control laws.

Appendix A offers detailed information about the features of systems used in the case studies. Appendix B resumes the main theoretical results supporting the sliding-mode, feedback linearization and QFT robust control methods. Finally, Springer

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