Wind turbine control and model predictive control for uncertain systems

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This thesis presents both an applied study and a theoretical study within the field of control theory. Control theory is an interdisciplinary branch between mathematics and engineering dealing with the manipulation of systems to produce a desired output. The applied study deals with wind turbine control. Wind turbines are controlled to optimize energy extraction from the wind. This must be done while respecting physical restrictions and ensuring that loads on the wind turbine structure does not seriously reduce the lifetime of components. This poses a trade-off in the design and the wind turbine problem is hence a complex multivariable problem. In this thesis the main focus is on design of controllers which optimally attenuates the impact of the variability in the wind. The angles of the wind turbine blades have been used as the primary control variable to achieve this goal. Strategies have been studied in which the blades are controlled collectively and individually. The wind has both temporal and spatial variations with a stochastic nature. Furthermore, the wind has deterministic (or slowly varying) trends. Large parts of the thesis hence deals with developing wind models which can be used as disturbance models for controller design. The theoretical study deals with Model Predictive Control (MPC). MPC is an optimal control method which is characterized by the use of a receding prediction horizon. MPC has risen in popularity due to its inherent ability to systematically account for time-domain constraints on signals. During the last decades several theoretical advances have been made, so that it can handle a wide variety of system structures. In this thesis, the focus is on handling uncertain linear system description. To this end the so-called Youla parameterizations have been used. Two methods are proposed: The first method exploits the modularity of the parameterizations so that the uncertainty can be identified and the MPC controller can be reconfigured in a modular setting. The second method is a robust MPC method in which the Youla parameters are used as an integral part of the online optimization. In this way stability can be guaranteed given an assumed bound on the uncertainty. The contributions of the thesis have been documented in a series of scientific papers. The papers form the main part of this thesis.

General information
Publication status: Published
Organisations: Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Thomsen, S. C.
Publication date: Sep 2010

Publication information
Place of publication: Kgs. Lyngby, Denmark
Publisher: Technical University of Denmark (DTU)
Original language: English
(IMM-PHD-2010-229).
Electronic versions:
phd229_sct-web.pdf
Source: orbit
Source ID: 258578