CAPABILITIES OF MODEL PREDICTIVE CONTROL FOR LOAD REDUCTION ON WIND TURBINES

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Abstract

The consideration of the interaction between the mechanical and the control system is crucial for dimensioning a mechatronic system. An example for such a system is a horizontal axis wind turbine (HAWT). Current HAWT have three blades and are pitch-controlled. The rotational speed can be controlled either by rotating the blades about their mean axis in order to change the pitch angle and thereby vary the aerodynamic torque of the rotor or by adjusting the generator torque. Both, pitch angle and generator torque, are used for a safe and efficient operation of the wind turbine.

State of the art control schemes for wind turbines are based upon proportional, integral and differential control principles. A typical controller setup of an industrial wind turbine is shown in Figure 1. As can be seen, the controlled variable of a wind turbine is the generator speed. If it differs from a reference speed the generator torque and the pitch angle are used to minimize this deviation. The main focus of such a scheme is the maximum power output and a safe operation especially in case of strong changes of the environmental conditions, such as a gust. The loads caused by the control actuation itself are a secondary aspect of these control principles. An overview on classical controller schemes for wind turbines are given by [1].

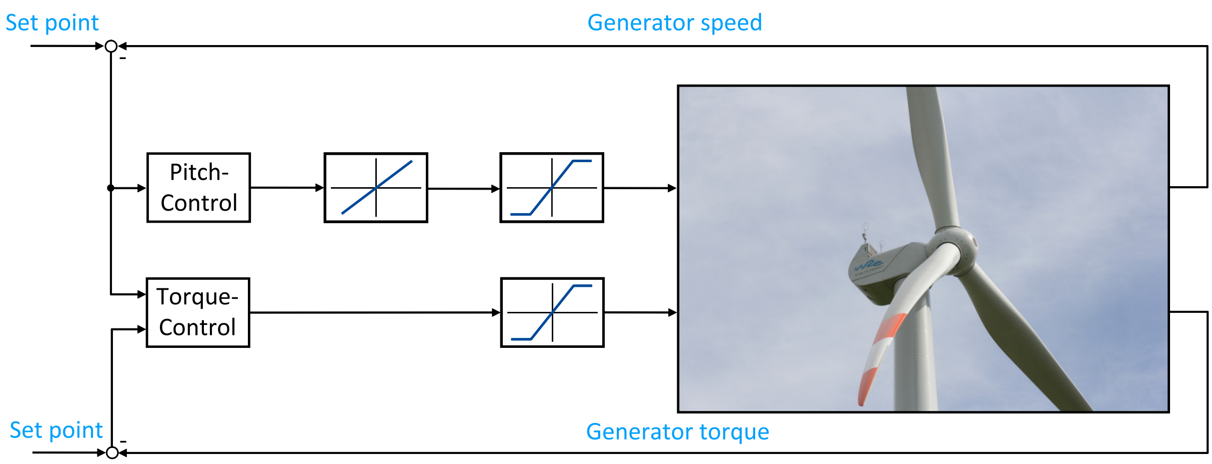

Figure 1: Classical control scheme of a wind turbine

Wind turbines are steadily growing in size and the structures, such as the blades, are becoming more and more flexible. This is accompanied by increasing mechanical loads acting on the wind turbine components. In order to minimize the impact of those loads, load alleviation strategies can be integrated into the control principles of wind turbines. To do so, mechanical loads can be measured and fed back into the controller. Different control schemes dealing with load alleviation strategies, based up on a combination of different single-input single-output (SISO) controllers, have been studied throughout the last years, see [2]. Alternatively to several separately tuned SISO controllers, multiple-input multiple-output (MIMO) controllers can be used to unify the different control loops in one single framework. An example for MIMO control, which has been paid more attention to in wind energy related research recently is Model Predictive Control (MPC), see Figure 2. In the MPC framework a simplified dynamic model of the system is used to predict the controlled outputs. The MPC computes a control sequence that is optimal with respect to an user defined cost function. This on-line optimization also considers constraints in order to guarantee the turbines operation within its limits. The unification of different control loops and their aims in one MPC allows for intuitive weighting of conflicting control aims, such as maximum power and load alleviation.

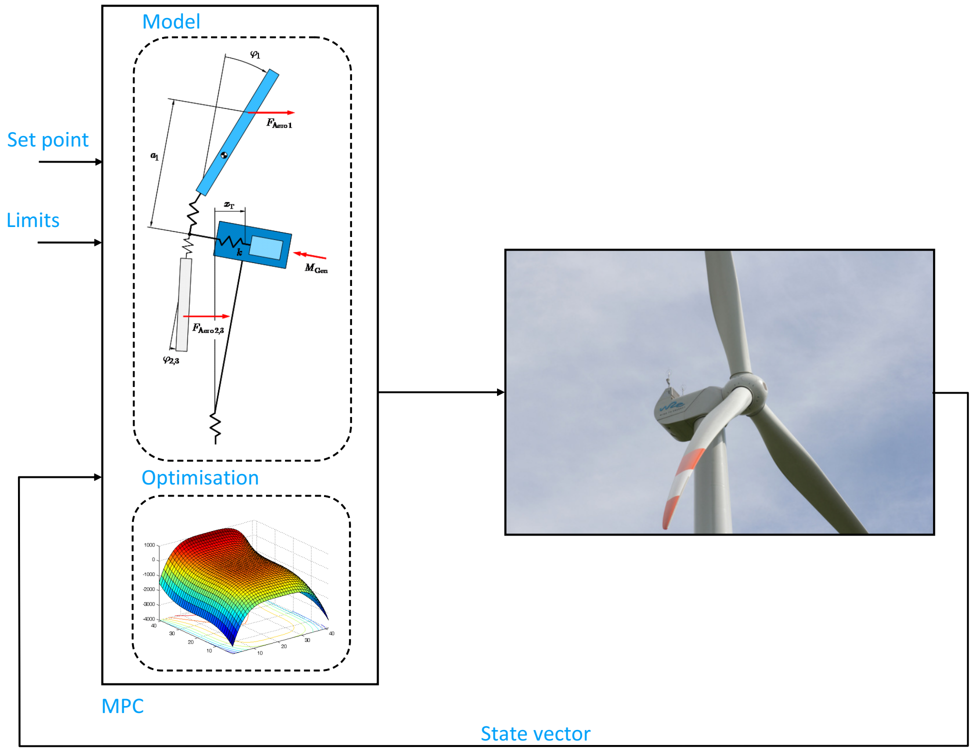

Figure 2: Model predictive control scheme of a wind turbine

In this paper the capabilities of MPC are compared to the classical control schemes. Therefore both controller principles are integrated in a multibody model of a 2.05 MW wind turbine created with the program package alaska/Wind. An extensive validation of the wind turbine model has been provided by [4]. First investigations based on a generic wind turbine model in SIMPACK show large load reduction capabilities using a MPC [5]. Beside the load reduction on main components also the energy production is considered for comparison.

References

[1] E.A. Bossanyi. The Design of Closed Loop Controllers for Wind Turbines. Wind Energy, Vol. 3, pp. 149–163, 2000.

[2] J.H. Laks, Lucy Y. Pao, A.D. Wright. Control of wind turbines: Past, present, and future. American Control Conference, 2009. ACC '09, pp. 2096–2103, June 2009.

[3] L. Henriksen. Model Predictive Control of Wind Turbines. Ph.D. thesis Technical University of Denmark, Informatics and Mathematical Modelling, Building 321, DK-2800 Kongens Lyngby, Denmark, 2010.

[4] J. Zierath, R. Rachholz, C. Woernle, A. Müller. Load Calculation on Wind Turbines: Validation of Flex5, alaska/Wind, MSC.Adams and SIMPACK by means of Field Tests. In Proceedings of the ASME 2014 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference, 2nd Biennial International Conference on Dynamics for Design (DFD), Buffalo, New York, USA, 2014.

[5] U. Jassmann, J. Berroth, R. Schelenz, M. Reiter, G. Jacobs, D. Abel. Model Predictive Control of a Wind Turbine modelled in SIMPACK. Journal of Physics: Conference Series, Vol. 524, p. 012047, 2014.