Gain Scheduling for Output $H_\infty$ Control of Offshore Wind Turbine

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ABSTRACT

This paper deals with gain scheduling and output feedback $H_\infty$ control design for an offshore floating wind turbine. The controller objective is to mitigate oscillations in the structure and drive train in addition to smoothening the power/torque output, by means of collective pitching of the blades. In this paper, the wind turbine model is obtained by using the software FAST. Inside the FAST package there are routines to obtain linear models at several operating points by considering the most critical degrees of freedom. The degrees of freedom in the linearized model are chosen according to the controller objective. These models are valid within the span of operating points. A family of controllers is designed based on a Lyapunov function and are formulated in terms of linear matrix inequality (LMI) techniques. The LMIs are solved using YALMIP interfaced with MATLAB. Then, the controller is tested on the fully nonlinear system, and compared with the baseline controller included in the FAST package.

KEY WORDS: Wind turbine, control, gain scheduling.

INTRODUCTION

Wind energy is a fast growing business, and it is nowadays one of the most promising sources for renewable energy. The growth in the wind power industry has been tremendous over the last decade. Since the early 1990s wind power has enjoyed a renewed interest, particularly in the European Union where the annual growth rate is about 20%. In order to sustain such growth, wind turbine performance must continue to be improved. The wind turbines are getting bigger and bigger which in turn leads to larger torques and loads on critical parts of the structure. This calls for a multi objective control approach, because we want to maximize the power output while mitigating the unwanted oscillations in the drive train and tower structure. In this paper we will focus on the above rated wind speed conditions, i.e. the control focus is on mitigating oscillations in critical parts and keeping the torque/power output as smooth as possible. In this case the torque reference is kept constant while pitch angle is being calculated by the controller. One of the major reason the wind turbine is a challenging task to control is due to the nonlinearity in the relationship between turning wind into power. The power in the wind is proportional to the third power of the wind speed.

Gain scheduling started to appear in technical papers in the beginning of the 1990s (Rugh, 1991; Shamma and Athans, 1990, 1991, 1992). Probably the most significant result was the definition of linear parameter varying (LPV) systems in (Shamma and Athans, 1991). The ability to define this kind of system has led to simpler and more efficient tools for gain scheduling control design. More information about the theory and the procedures can be found in (Bianchi et al., 2007) and the references therein.

Recently, linear controllers have been extensively used for power regulation through the control of blade pitch angle in wind turbine systems (Skaare et al., 2007; Jonkman, 2008; Namik and Stol, 2009; Christiansen et al., 2011; Wayman et al., 2006; Hanson et al., 2011). However, the performance of these linear controllers is limited by the highly nonlinear characteristics of wind turbine. Advanced control is one research area where such improvement can be achieved. On the other hand, over the last three decades, considerable attention has been paid to robustness analysis and control of linear systems affected by structured real parameters. An LPV system can be viewed as a nonlinear system that is linearized along a trajectory determined by the parameter vector. Hence, the parameter vector of an LPV system corresponds to the operating point of the nonlinear system. In the LPV framework, it is assumed that the parameter vector is measurable for control. In our case the scheduling parameter is the wind speed, i.e. the