Mechatronics 21 (2011) 668–681

Contents lists available at ScienceDirect

Mechatronics

journal homepage: www.elsevier.com/locate/mechatronics

# The use of preview wind measurements for blade pitch control

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ARTICLE INFO

*Article history:*
Available online 5 March 2011

*Keywords:*
Wind turbine
Preview control
Independent pitch
H-infinity
Load mitigation
Feedforward

ABSTRACT

Light detection and ranging systems are able to measure conditions at a distance in front of wind turbines and are therefore suited to providing preview information of wind disturbances before they impact the turbine blades. In this study, preview-based disturbance feedforward control is investigated for load mitigation. Performance is evaluated assuming highly idealized wind measurements that rotate with the blades and compared to performance using more realistic stationary measurements. The results obtained using idealized, "best case" measurements show that excellent performance gains are possible with reasonable pitch rates. However, the results using more realistic wind measurements show that without further optimization of the controller and/or better processing of measurements, errors in determining the shear local to each blade can remove any advantage obtained by using preview-based feedforward techniques.



## 1. Introduction

The stochastic nature of the wind resource and the high initial capital cost and increasing, structural flexibility of utility scale turbines motivate the adoption of advanced instrumentation and measurement technologies. One of the most attractive technologies is LIDAR (light detection and ranging) that has the ability to make real-time measurements of wind conditions local to individual turbines. These types of measurements make it possible to employ disturbance feedforward techniques using actual wind measurements instead of employing wind estimates obtained from measurements of the turbine structural dynamics. In a previous study [1], using feedforward control without preview, it was found that in non-turbulent conditions (but still time varying), controller performance is improved when using an aggregate measurement of wind such as horizontal hub height speed (HHS). However, in turbulent wind conditions, it was found that measurement of wind conditions local to each blade were necessary to improve controller performance. Further, it was found that disturbance feedforward based on HHS alone could actually be detrimental depending on the aggressiveness of the feedforward controller. Unfortunately, any improvement over and above that obtained using well-tuned feedback control came at the expense of excessive pitch rates. The results presented in this paper show that excessive pitch rates can be avoided when measurements provide a preview of disturbances before they impact the turbine.

### 1.1. Control architecture

The variation of feedforward control known as preview [2] is illustrated in Fig. 1 and is distinguished by the use of advance knowledge of imminent disturbances (or commands). This technique is feasible using LIDAR technology since LIDAR is most easily configured to measure wind approaching the turbine rather than at the turbine and, hence, there are measurements available of incoming wind perturbations before they impact the turbine.

Additionally, depending on the LIDAR scanning pattern, it is feasible to determine wind components in either rotating or non-rotating reference frames as with multi-blade coordinates (MBC). As explained in detail in Bir [3], MBC coordinates transform quantities or measurements that rotate with the blades into non-rotating components. This transformation can be used on the dynamics of the turbine model as in Appendix B.2 and in this application it is often referred to as the Coleman transformation [4].

In this study we explore the load mitigation performance of $\mathcal{H}_\infty$ non-MBC and MBC based preview controllers relative to collective pitch feedback-only, and MBC, independent pitch feedback-only controllers. The preview controllers have access to time-advanced measurements of wind speed in addition to the feedback from generator speed error and blade-root bending-moment perturbations that the feedback-only controllers use. Simulations are performed using the turbine modeling code FAST [5] developed at the National Renewable Energy Laboratory's (NREL's) National Wind Technology Center (NWTC) with a model of NREL's three-bladed controls advanced research turbine (CART3). All simulations are done with a mean wind speed of 18 m/s that places the CART3 squarely in above rated (region 3) conditions where

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doi:10.1016/j.mechatronics.2011.02.003