IPID4all Doctorate Research Exchange with the Dynamics and Controls group at the department of Electrical, Computer and Energy Engineering (ECEE) at the University of Colorado, USA

Feedback report

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Exchange topic: *Blade mounted LiDAR based feedback-feedforward individual pitch and trailing edge flap control of wind turbines.*

Introduction

To reduce the overall cost of wind energy, the trend of increasing wind turbine size is continuing. However, this leads to a strong increase of weights and loads across the wind turbine components. This motivates to investigate a new sensor and control technologies such as blade mounted LiDAR based feedback-feedforward control of trailing edge flap and individual blade pitch angle.

Research Undertaken

During the exchange I introduced a continuous wave LiDAR system with a blade mountable telescope into a high fidelity aeroelastic horizontal axis wind turbine simulation code (HAWC2), where I investigated the optimal sensor setup, such as measurement angle, focus distance, and position of the telescope along the blade span with respect to the correlation between the measured inflow wind speed and blade effective wind speed. The blade effective wind speed estimation also had to be introduced into the simulation environment, which is determined as the contribution of the horizontal wind speed on each blade segment to the flapwise blade root bending moment. The contribution depends on the radial distance and thrust coefficient of the blade segment.

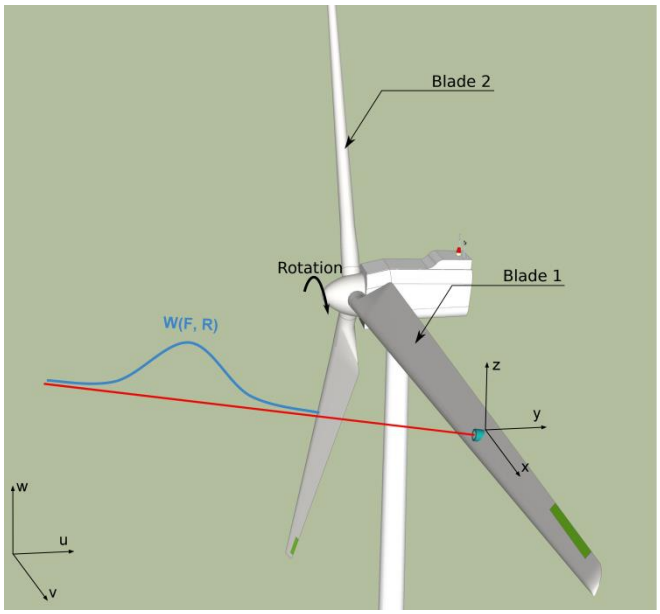

Figure 1: LiDAR measurement configuration, where a telescope is mounted on each blade and is connected through fiber optics to a continuous-wave LiDAR placed in the hub. The LiDAR is sampling the inflow wind speed in front of the wind turbine blade at a sample rate of 50 Hz, and the measurements are used to control the next blade's flap and pitch angle.

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By measuring the inflow wind speed with a LiDAR system before reaching the wind turbine blades, gives the possibility to extend the feedback with feedforward individual pitch and trailing edge flap control. The objective of the LiDAR-based inflow wind speed measurement is to use it for feedforward control. Figure 1 shows the order of the blades and the rotation direction. The measured line of sight wind speed with the telescope mounted on Blade 1 is used to control the trailing edge flap and pitch angle of the next blade, namely Blade 2. During the exchange, the H_∞ based feedback control loop is extended with an inverse based feedforward control loop with the aim of the disturbance rejection. During my stay, I was able to finish the planed tasks; the results are promising with respect of the damage equivalent load reduction on the wind turbine components. The results will be published in an upcoming joint publication.

Personal Experience

During the exchange period, I had the opportunity of a side tour at the National Wind Technology Center (NWTC) at NREL. This gave me the chance to establish connection and have an insight of the research focus of the groups. At the end of my stay, I also had the opportunity to present my work as a seminar speaker at the NWTC.
On one hand, Boulder is located close to the Rocky Mountains, which gave a lot of opportunities for outdoor activities with the group. On the other hand, several social events were organized during my stay, such as football tournament, NWTC site visit, or joint dinners, where I had the chance to participate as a group member. Overall, this made it easier to socialize and feel as a permanent member of that group.

Conclusions

I had a successful exchange period at the Dynamics and Controls group at the department of Electrical, Computer and Energy Engineering (ECEE) at the University of Colorado. The exchange gave me the opportunity to fill the knowledge gap with respect to LiDAR based feedforward control giving me a boost to further proceed with my research. The weekly meeting with Prof. Dr. Lucy Y. Pao started great scientific discussion which helped me to further proceed with my work and achieve my primary research goals. This includes the development of the LiDAR based measurement methodology which later is used as the feedforward control input. By extending the feedback with an inverse based feedforward control, additional load reduction is achieved. On the personal level I could establish relationship not only within the Dynamics and Controls group but also at the National Wind Technology Center, which could be the base for further cooperation including field test of the LiDAR based wind speed measurement methodology developed during this exchange period.

Outlook

The main outcome of the exchange is a planned joint publication, which includes the proposed methodologies and the archived load reduction with feedback—feedforward control of the combined pitch and trailing edge flap system.
Further exchange and cooperation are expected, within the “Hanse-Wissenschaftskolleg” program Prof. Dr. Lucy Y. Pao will be a visitor researcher at ForWind, University of Oldenburg for a period of eight months. During the exchange her main focuses will be the advance control of wind turbines and wind farms with the aim of load reduction and power optimization. This involves further researchers from the research group Wind Energy Systems. It is expected further cooperation in numerical simulations and wind tunnel tests of wind turbines and wind farms controls.

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