IPID4all Doctorate Research Exchange with University of Oldenburg
Feedback report

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Controls for a Segmented Ultralight Morphing Rotor

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Introduction

I had initially proposed studying the application of smart rotor control to my project: a segmented, ultralight, morphing rotor (SUMR), which is funded by the United States Advanced Research Projects Agency for Energy (ARPA-E). The current goal of my project is to reduce the levelized cost of energy (LCOE) for a 13 MW downwind, 2-bladed rotor. After conducting initial research, we concluded that smart rotor control, while an interesting research topic, might not lead to the cost savings that we are hoping to achieve.

With the help of my advisers at the University of Oldenburg, we took a deeper look at what control actions have a large impact on the cost of energy. We determined that reducing the peak blade loads would allow our team to integrate the control system design with the blade's structural design. By constraining the peak blade loads and optimizing the power capture, this could lead to the greatest LCOE reductions. Peak blade loads depend on the average blade load and load amplitude, both of which can be controlled.

Research Undertaken

1. Before my research exchange, we used individual pitch control to reduce periodic load amplitudes. During my exchange, I incorporated robust design methods (H-infinity loop shaping) to reduce periodic loading that contributes to peak blade loads.

2. To reduce the mean blade loads, the transition region between above- and below-rated operations required analysis and redesign. A few different control methods were explored. There are many ways to accomplish this task, with varying degrees of effectiveness and cost. Reducing peak loads requires some amount of power loss, which increases the LCOE. I am currently examining the trade-off between power and peak loads of various control methods. However, reliably constraining the peak loads while maximizing power could enable different initial rotor designs.

3. I supported my ARPA-E project by testing controllers on a series of rotors to analyse LCOE trade studies. Namely, we looked at rotors with various cone angles to study the resulting extreme and fatigue loading.

Personal Experience

The group of students and professors at the ForWind were incredibly supportive and inclusive. We shared dinners, after-work drinks and adventures to the lake. Using a connection from the University of Oldenburg, I rented a room in the home of a German family, who shared many stories and made me feel at home. I played Ultimate Frisbee with a local team, travelled with them to a tournament and made many friends there, which helped me to integrate quickly during my short stay.

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I utilized the Deutsche Bahn to visit colleagues in Stuttgart, Delft and Copenhagen; and travelled for pleasure to Switzerland, Ireland, Italy and Austria. I also presented my work at two conferences, making new connections in the wind energy industry.

Conclusions
During my research exchange, I was able to gain valuable perspectives on my work in order to formulate a plan towards finishing my degree. This will be my most valuable takeaway, along with the many connections formed during my exchange.

Outlook
- Postdoc Vlaho Petrovic provided valuable insight into control methods for peak load shaving; we hope to collaborate on a future research paper.
- During the Wind Energy Science Conference, I connected with a researcher from the Fraunhofer Society who designs blade pitch actuators. We are working together on a study to detail the impact of individual pitch control on actuator design and cost.
- Misha Sinner and Chris Bay from the University of Colorado recently visited the University of Oldenburg. Dana Martin, from the Colorado School of Mines, my partner on the SUMR project, is currently doing an IPID4all exchange.

DAAD

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