June 2016

Details
IEA WIND Task 32 Workshop #2 on

Optimizing Lidars for Wind Turbine Control Applications

Date: July 5th 2016
Venue: Boston Marriott Copley Place, Boston, MA, USA
Immediately preceding the 2016 American Control Conference
Workshop leader: Eric Simley, Envision Energy

Concept

In this workshop, the optimization of lidar systems for control applications will be addressed using input from wind turbine manufacturers, the lidar industry, and the academic community. The requirements or "objectives" of lidars for control purposes will be defined, particularly with suggestions from participants from wind turbine manufacturers. Lidar design considerations or "constraints" will be incorporated based especially on guidance from participants in the lidar industry. Lastly, models for calculating lidar measurement accuracy, based on contributions from the research community, will be used to determine the effectiveness of different lidar measurement strategies and help solve the lidar optimization problem. Specifically, a frequency-domain wind field model including a simple model of wind evolution will be used to determine measurement error. Additionally, time-domain control simulations will be used to investigate the impact of measurement error on control performance and how practical issues such as measurement filtering and time-of-arrival uncertainty affect control performance. The workshop will begin with invited presentations from participants from research organizations, wind turbine manufacturers, and lidar suppliers. Workshop attendees will then participate in collaborative exercises examining how different lidar parameters, scan patterns, and controller features affect measurement quality. The program will also include roundtable discussions, allowing all participants to share their perspectives on optimizing lidar systems for control applications and help shape the outcome of the workshop.

Expected Outcome

A report describing requirements and recommendations for lidar systems for wind turbine control applications will be compiled based on the results of the workshop and any follow-up exercises. The report will contain both results from theoretical investigations and practical considerations. Follow-up meetings will be held remotely so that workshop attendees can collaborate on the document, with a target completion date of December 2016. Once finalized, the report is to be published as a tutorial

paper in an appropriate journal, to be defined at a later time, and made available to stakeholders in the lidar and wind energy communities.

Prior to the workshop, a draft outline of the report will be made available here: https://goo.gl/A5zs9q

Program

8:30	Welcome/Introduction to IEA Wind Task 32 (David Schlipf, SWE, University of Stuttgart)
8:45	Introduction to workshop (Eric Simley, Envision Energy)
9:00	Introduction to lidar-assisted control (Andy Scholbrock, NREL)
9:30	Requirements and objectives of lidar systems for control purposes from the wind turbine manufacturers' perspective (Conner Shane, GE; Bin Wang, Goldwind)
10:15	Coffee break
10:30	Design considerations and constraints for lidar systems for control purposes from the lidar industry's perspective (Matthieu Boquet, Avent; Shumpei Kameyama, Mitsubishi and Hirokazu Kawabata, AIST; Chris Slinger, ZephIR)
11:30	Roundtable discussions on lidar-assisted control objectives and current barriers for lidar for wind turbine control (small group discussions)
12:30	Lunch (Fogo de Chao)
1:45	Sources of lidar wind speed measurement error for control applications (Eric Simley, Envision Energy)
2:15	Exercise 1: Investigating how lidar parameter and scan pattern choices impact measurement quality (group exercise, leader: Eric Simley, Envision Energy)
3:15	Coffee break
3:30	Exercise 2: Investigating how lidar measurement error, measurement filtering and wind speed time-of-arrival uncertainty impact controller performance (group exercise, leader: Holger Fürst, SWE, University of Stuttgart)
4:30	Roundtable discussions on lidar system optimization for control applications (small group discussions)
5:30	Workshop wrap-up and formulation of next steps, including preparation of the final report (group discussion)
6:00	End of workshop
7:30	Dinner (location TBD)

Program Details

Roundtable discussions on lidar-assisted control objectives and current barriers for lidar for wind turbine control

The outcome of the discussion will be a list of control objectives that lidar optimization should be considered for as well as a list of barriers that need to be overcome to allow the widespread use of lidars for control.

Exercise 1: Investigating how lidar parameter and scan pattern choices impact measurement quality

Learning Objectives: To understand the concept of lidar measurement coherence, which can be used to analyze the quality of lidar measurement scenarios. Measurement coherence can be directly calculated using spectral wind field models without having to perform any time-domain simulations. We will investigate how concepts such as the type of scan pattern, wind evolution, line-of-sight limitations, and spatial averaging affect measurement quality by examining measurement coherence and mean square measurement error. The conclusions from this exercise can help guide the next roundtable discussion.

Exercise details and MATLAB code can be found here:

www.ieawindtask32.org/wp-content/uploads/ws02/IEAWindTask32_WS02_Ex1.zip

Please refer to IEAWindTask32_WS02_Ex1_Notes.pdf for the exercise instructions.

Exercise 2: Investigating how lidar measurement error, measurement filtering, and wind speed time-of-arrival uncertainty impact controller performance

Learning Objectives: To understand how wind preview signals can be used to improve wind turbine control, using collective pitch control as an example. Participants will investigate how theoretical generator speed spectra, calculated using methods introduced in exercise 1, and spectra from time-marching simulations match and why coherence is a good measure of how the control performance is impacted. In addition, wind preview filtering and timing are important design considerations and without solid understanding of these two issues feedforward control can generate more harm than benefit. The conclusions from this exercise can help guide the next roundtable discussion.

Exercise details and MATLAB code can be found here:

www.ieawindtask32.org/wp-content/uploads/ws02/IEAWindTask32_WS02_Ex2.zip

Please refer to IEAWindTask32_WS02_Ex2_Notes.pdf for the exercise instructions.

Roundtable discussions on lidar system optimization for control applications

The outcome of the discussion will be a list of design suggestions that can mitigate the barriers preventing the widespread use of lidar-assisted control and a list of design suggestions for optimizing lidars for the identified control applications, taking into account the design constraints identified by the lidar industry. The outcome of this discussion will form a starting point for the material to be included in the workshop report.

Dinner

After the workshop, those participants who are attending the ACC are encouraged to attend the opening reception at 7pm. Those who will not be attending the opening reception are invited to join for dinner at 7:30pm at a nearby restaurant (TBD).

Participant List

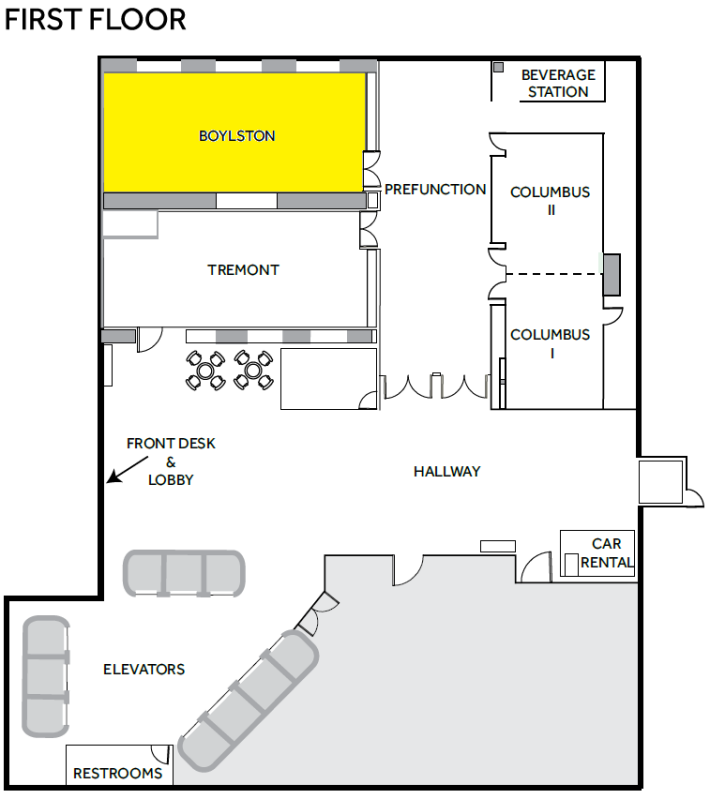
Name	Country	Institution
Alan Wright	USA	NREL
Andrew Scholbrock	USA	NREL
Bin Wang	China	Goldwind
Bryan Williams	USA	GE
Cédric Arbez	Canada	TechnoCentre Éolien
Chris Slinger	UK	ZephIR
Conner B. Shane	USA	GE
Daniel Zalkind	USA	University of Colorado Boulder
David Schlipf	Germany	SWE University Stuttgart
Dhiraj Arora	USA	GE
Eric Simley	USA	Envision Energy
Evan G. Osler	USA	Renewable NRG Systems
Florian Haizmann	Germany	SWE University Stuttgart
Guilin Zhou	China	Goldwind
Hirokazu Kawabata	Japan	Advanced Industrial Science and Technology
Holger Fürst	Germany	SWE University Stuttgart
Jan-Willem van Wingerden	Netherlands	TU Delft
Justin Creaby	USA	Siemens
Kathryn Johnson	USA	Colorado School of Mines
Lei Liu	China	Goldwind
Lucy Pao	USA	University of Colorado Boulder
Mahmood Mirzaei	Denmark	DTU Wind Energy
Matthieu Boquet	France	Avent
Michael Hind	USA	Siemens
Nikolas Angelou	Denmark	DTU Wind Energy
Nobuki Kotake	Japan	Mitsubishi Electric Corporation
Paul Fleming	USA	NREL
Pierino Bonanni	USA	GE
Raach Steffen	Germany	SWE University Stuttgart
Róbert Ungurán	Germany	University of Oldenburg
Romain Goussault	France	IFPEN
Roozbeh Bakhshi	USA	University of Maryland-College Park
Sachin Navalkar	Netherlands	TU Delft
Shumpei Kameyama	Japan	Mitsubishi Electric Corporation

Venue Information

The meeting will be held at the Boston Marriott Copley Place in downtown Boston, MA, USA:

Boston Marriott Copley Place
110 Huntington Avenue
Boston, Massachusetts 02116 USA

Location and transportation information for the venue can be found on the hotel website (http://www.marriott.com/hotels/maps/travel/bosco-boston-marriott-copley-place/). The workshop will be held in the **Boylston** meeting room on the 1st floor (see map below).



http://www.marriott.com/hotels/event-planning/business-meeting/bosco-boston-marriott-copley-place/