

IPID4all Senior Research Exchange with University of Colorado, Colorado School of Mines and Nat. Renewable Energy Laboratory, Colorado, US

Feedback report

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*Topic: International cooperation in wind energy
research and teaching*

Visited institutions

1. *University of Colorado, Prof. Dr. Lucy Pao, Dept. of Electrical, Computer, and Energy Engineering, Engr Ctr EE 1B55, 80309-0425 Boulder, CO, US*
2. *Colorado School of Mines, Prof. Dr. Kathryn Johnson, Department of Electrical Engineering, 1610 Illinois Street, Golden, CO 80401, CO, US*
3. *National Renewable Energy Laboratory, Dr. Alan Wright, National Wind Technology Center, 18200 CO-128, Boulder, CO 80303, CO, US*

Activities / Contacts

The objective of my visit to Boulder, Colorado, US was to strengthen the ongoing cooperation with two universities and a research center situated in this region as well as to contribute to the development of a long-term research plan of the IEA Wind. The journey was triggered by two adjacent events, the Topical Expert Meeting of the IEA Wind (22.-23.10.2017) and the WindTech 2017 conference (24.-26.10.2017) both held in the area of Boulder. Another reason for me to travel was to respond to several exchanges between Boulder and Oldenburg during the last two years. The IPID4all program facilitated two outgoing (R. Unguran, L. Vollmer) and four incoming PhDs/PostDoc (D. Zalkind, M. Sinner, C. Bay, D. Martin). Furthermore Prof. L. Pao did an 8-months lasting fellowship at the Hanse-Wissenschaftskolleg (HWK) in the field of control of wind turbines and wind farms.

The comprehensive program started on October, 20th at the **University of Colorado (CU)** by subsequently discussing numerical fluid dynamics in the wind energy field with three senior faculty member (J. Brasseur, P. Hamlington and K. Jansen) of the aerospace and mechanical engineering department. Next together with our PhD researcher M. Bromm a meeting took place with **Prof. J. Lundquist** (CU, Atmospheric and Oceanic Sciences, and NREL - National Renewable Energy Laboratory) and her PhD students on cooperation in large eddy simulation and lidar measurements of atmospheric wind farm flow. End of 2016 our PhD researcher L. Vollmer spent a two months exchange at the group of Prof. Lundquist which was funded by IPID4all. Together with M. Bromm we gave a seminar entitled »Wind Physics at the University of Oldenburg – An Interdisciplinary, Multi-Scale Program for Research and Teaching in Wind Energy« at the university and discussed with staff and students. The day was rounded off by individual meetings with five PhD students of my main host **Prof. L. Pao**, Department of Electrical, Computer, and Energy Engineering on the ongoing cooperation in control of wind turbines and wind farms.

On October 30th a farewell meeting with Prof. L. Pao took place where the entire Boulder visit and the further plans were elaborated.

On October 22nd and 23rd the **Task 11 - Topical Expert Meeting # 89 »Grand Vision for Wind Energy: Next Technology and Infrastructure Challenges to Realize Wind's Full Potential«** of the IEA Implementing Agreement on Wind Energy (IEA Wind) took place with approx. 50 selected international experts at the National Renewable Energy Laboratory (NREL), Golden, CO. In this workshop aimed to provide input and insights associated with scenarios that yield aggressive wind industry growth globally. The focus was on wind turbine and wind plant technology and

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associated wind industry and electric system infrastructure advances. Questions of the intensive and fruitful discussions included:

- What conditions affect wind growing incrementally until it is a dominant source for global electricity generation in 2030/2050?
- What are R&D challenges that arise in an aggressive (paradigm shifting) growth scenario relative to incremental growth?
- What innovative infrastructure developments would support aggressive wind deployment? What is the current state-of-the-art in these technologies and what are the major challenges with these systems in realizing a wind energy dominant electricity grid of the future?
- How does wind turbine and wind plant technology need to evolve to meet different infrastructure developments and different market contexts (e.g., established vs. emerging)?

From October 24th to 26th the **WindTech 2017 Conference** was held with approx. 150 international scientists at the National Center for Atmospheric Research (NCAR), Boulder, CO. ForWind – University Oldenburg was participating with six oral and one poster presentations, incl. four contributions from our research group. The event provided an excellent opportunity to get an overview on ongoing research in the US and to meet researchers from both the US and Europe.

In the afternoon of October 26th the ForWind staff was invited to a visit of the National Wind Technology Center (NWTC) of the **National Renewable Energy Laboratory** (NREL), arranged by Dr. A. Wright. Pitches of our four ForWind PhD researchers J. Schottler (AG TWiSt), I. Neunaber (AG TWiSt), F. Berger (AG WESys) and A. Rott (AG WESys) were integrated in my 90 minutes speech on wind physics at the University of Oldenburg and initiated a fruitful discussion with 20 staff members of NWTC. An extensive excursion of the research infrastructure including open field test turbines and testing facilities for wind turbine blades and drive trains completed this tour. Of particular interest was climbing up the CART3 research turbine.

In the afternoon of the next day, an intensive meeting on extension of the cooperation between ForWind and NREL respectively the two universities took place with senior NREL staff incl. the NWTC Director Paul Veers, Prof. L. Pao and Prof. J. Johnson. In addition, the further collaboration was discussed in detail with Dr. C. Bay, PostDoc at the groups of Prof. L. Pao, Prof. J. Johnson and NWTC.

An excursion of the ForWind delegation to the **Colorado School of Mines** (CSM), Golden, CO was organized by Prof. Kathryn Johnson for the morning of October 27th. I had two meetings with four professors from the control and mechanical engineering department while the PhD students took a campus tour. Furthermore, aspects of PhD research were discussed in a joint meeting of the PhD researchers of ForWind and of the PhD students of Prof. Johnson. Subsequently the wind tunnel of the Center for Experimental Study of Subsurface Environmental Processes was visited.

Future collaboration / Outlook

The comprehensive visit of several events and research groups in Colorado will leverage further cooperation of our own research group Wind Energy Systems (WESys) and the above-mentioned US institutions.

Despite the fact that funded joint research projects of German and American institutions are extremely rare in the field of wind energy, a strong willingness of the visited researchers and our

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group to extend the already ongoing collaboration was expressed and several concrete plans were discussed. Planned activities include:

- Journal paper of R. Unguran et al. (WESys) and L. Pao on feedforward control of wind turbines with active trailing edge flaps (under review)
- Journal paper of B. Shestha et al. (WESys) and L. Pao on load mitigation of offshore wind turbine by adaptive control (in preparation)
- Journal paper of L. Vollmer (supervised by M. Kühn) et al. and J. Lundquist on coupled mezoscale and large eddy simulations (in preparation)
- lab experiments on new control concepts with a \varnothing 1.8m model wind turbine in the new wind tunnel of ForWind during the year 2018 following up on the IPID4all exchange of M. Simer (CU), D. Martin (CSM) and C. Bay (CU, CSM, NREL) leading to at least two journal papers or peer-reviewed proceedings
- Lidar measurement campaign of ForWind at the CART3 test turbine at NREL within the German SmartBlades2.0 project in 2018/19. The prospects of additional lidar measurements in another NREL project will be further investigated.
- Cooperation in the field of wind farm control between A. Rott, M. Bromm and V. Petrovic (WESys), P. Fleming et al. (NREL) and L. Pao (UC, NREL)
- Cooperation on hardware-in-the-loop testing of control algorithms on wind turbines in the wind tunnel or open field between A. Scholbrock (NREL) and WESys
- Further collaboration in scope of the IEA Wind Task 32 Lidar between WESys and A. Scholbrock et al. (NREL)

Further planned exchanges

- Visit of D. Zalkind, UC to ForWind in the beginning of January 2018
- Possible visits of D. Martin, CSM and/or M. Sinner, CU for lab experiments with a \varnothing 1.8m model wind turbine in the new wind tunnel of ForWind during the year 2018
- Visit of PostDoc V. Petrovic, ForWind to UC (Prof. L. Pao), CSM (Prof. K. Johnson) and NREL (A. Wright) in July 2018 (before or after the ACC 2018 conference in Philadelphia)
- Visit of several staff members of ForWind in the scope of a lidar measurement campaign of ForWind at the CART3 test turbine at NREL from mid July 2018 to mid June 2019
- 2nd HWK Fellowship of Prof. L. Pao in the year 2019
- NREL staff and Prof. R. B. Cal, Portland State University, US expressed high interest in HWK Fellowships for junior or senior staff

Moreover, it is intended to establish a Memorandum of Understanding or similar agreement between NREL and ForWind – University Oldenburg to facilitate the further collaboration.