

# IPID4all Doctorate Research Exchange with Delft University of Technology

## Feedback report

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Exchange period:  
01.07.2015-31.09.2015

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Host supervisor:  
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Exchange topic:

### **Control-oriented wind farm modeling**

#### **Introduction**

This report is prepared regarding the fruitful collaboration between WE-Sys research group at University of Oldenburg and DCSC at TU Delft in the wind farm control, during my exchange experience through the IPID4all program. Considering the research questions of my Ph.D. topic, entitled “Wind Turbine control to optimized loads and energy yield with respect to real flow conditions in wind farms”, the expertise of the two research groups involved is complementary. Dr. Wingerden’s research group at DCSC carries out research on control of wind energy systems. WE-Sys expertise in field measurements, sensory systems and numerical studies of wind farm boundary layers complements the realization and validations of controllers with respect to realistic and practical conditions. My research stay established a fruitful collaboration in wind farm modeling and control yielding several achievements e.g. four published conference papers so far, three other short visits from both institutes and a new collaboration on another Ph.D. project.

#### **Research Undertaken**

The main research goal, involving several Ph.D. projects, is to develop a closed-loop model-based wind farm control framework. The control of turbines within a wind farm is challenging due to their aerodynamic interactions through wakes, which depend strongly on the effects of different wind directions, local terrain and the layout of a given wind farm.

My research exchange started with contributions to develop a medium-fidelity wind farm model for control purposes. A control-oriented model should capture dominant wind flow dynamics within a wind farm, in a computationally inexpensive manner. The constructed model has the standard state-space form, suitable to apply control theories, e.g. model predictive control, model order reduction and disturbance rejection to improve the performance of wind farms. The outcomes of the collaborative research during my stay are summarized in a following paper:

- 1- S. Boersma, **M. Vali**, M. Kühn and JW. van Wingerden, *Quasi linear parameter varying modeling for wind farm control using the 2D Navier-Stokes equations*, Proceeding of the 2016 American Control Conference (ACC2016), July 2016, Boston, U.S.A.

Furthermore, I had this chance to present the status of my research efforts in the active load control of wind turbines via multivariable individual pitch control. The encountered challenges from control engineering perspectives were discussed to improve the performance of wind turbine control system

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in mitigation of dynamic loadings. The modified results are summarized and published in the following conference paper as well:

- 2- **M. Vali**, JW. van Wingerden and M. Kühn, *Optimal multivariable individual pitch control for load reduction of large wind turbines*, Proceeding of the 2016 American Control Conference (ACC2016), July 2016, Boston, U.S.A.

## Personal Experience

I did my exchange visit at DCSC, TU Delft for three months in the summer of 2015. During my exchange, I had this opportunity to focus on learning and extending my knowledge in methods used in wind energy control systems. I had the chance to present my previous research work in the area of wind turbine and wind farm control and to discuss the challenges I encountered. Furthermore, I have been able to establish a good network and also enjoyed the social life along with my research. After one and half year, this network has extended and now I know many new PhD students with similar research topics. It has accelerated my progress in PhD studies due to the open discussions and sharing the new findings within this network.

## Conclusions

My research exchange through IPID4all leads to many benefits from different professional and personal aspects. It was a beginning to fruitful research collaboration on my Ph.D. topic between DCSC, TU Delft and ForWind, Uni Oldenburg. We have continued this research collaboration after the exchange period, yielding several publications in the reputed control engineering and wind energy conferences. Our research plan is continuously being developed to tackle more challenging problems and our academic network is growing positively as well.

## Outlook

- The research collaboration between two institutes has been continued after my research stay by further plans: 1) to extend and validate the control-oriented wind farm model, the so-called WFSim at TU Delft and 2) to develop a closed-loop optimal control framework for wind farms at WE-Sys. Three extra short research visits from both institutes have been arranged in 2016 for sharing and updating the different aspects of our research plan.
- The new outcomes of our collaboration after my research stay through IPID4all are published so far as two papers in TORQUE2016 and one full paper submitted to IFAC2016:
  - 3- **M. Vali**, JW. van Wingerden, S. Boersma, V. Petrovic and M. Kühn, *A predictive control framework for optimal energy extraction of wind farms*, Proceeding of the Science of Making Torque from Wind (TORQUE 2016), October 2016, Munich, Germany.
  - 4- S. Boersma, PMO. Gebraad, **M. Vali**, BM. Doekemeijer and JW. van Wingerden, *A control-oriented wind farm flow model: "WFSim"*, Proceeding of the Science of Making Torque from Wind (TORQUE 2016), October 2016, Munich, Germany.
  - 5- **M. Vali**, V. Petrovic, S. Boersma, JW. van Wingerden and M. Kühn, *Adjoint-based model predictive control of wind farms: Beyond the quasi steady-state power*

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*maximization*, Submitted to the 20<sup>th</sup> World Congress of the International Federation of Automatic Control (IFAC2017), July 2017, Toulouse, France.

- This fruitful collaboration is ongoing and growing. Andreas Rott, a PhD student from WE-Sys has been at DCSC since summer of 2016, to extend the collaboration of the two groups in the field of wind farm modeling and control.
- The research collaboration has been extended more to cooperate with other research groups, e.g. En-Met at University of Oldenburg. The plan is to develop and implement the investigated closed-loop optimal wind farm controller on the LES-based wind farm boundary layer environment, which is developed by En-Met group.

# DAAD



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