IPID4all Doctorate Research Exchange with Carl von Ossietzky University
Feedback report

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Exchange period: 1-31 October
Exchange topic: Validation of a control oriented model and setting up an control application using this model.

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Introduction

In Delft, we developed a control-oriented dynamic wind farm model named WFSim. The objective is to employ the model in online wind farm control applications, hence the model should be relatively inexpensive from a CPU point of view. In other words, the simulation time should be smaller than the time that is simulated. This is not a characteristic of standard wind farm models that are based on Large Eddy Scale Simulations (LES), referred to as high-fidelity models. Assumptions regarding physical behaviour in a wind farm had to be made in order to keep the developed wind farm model control-oriented, and one question is: can the control-oriented model still estimate real wind farm behaviour? Since real wind farm data is not always available, a good substitution can be found in data from a high-fidelity wind farm model. This data can be used for validation of the control oriented model developed in Delft.

In previous work, we validated the WFSim model with wind farm data computed with Simulator fOr Wind farm Applications (SOWFA), a high fidelity wind farm model developed in the National Renewable Energy Laboratory situated in Boulder. In the ForWind laboratory, a different high fidelity wind farm model named PALM is used. It is interesting to study if the WFSim model is also able to estimate PALM data.

The validated WFSim model will then be employed in an adjoint based model predictive controller, which optimizes the quality of the generated wind farm power. Previous work illustrated the possibilities, however there, the model used in the controller and the simulation model are equal making the results not reliable. The objective is therefore to use the validated WFSim model only in the controller, and replace the current employed simulation model by PALM. The latter will in this work then be regarded as a real wind farm. The proposed setup represents more the reality since the model employed in the controller will be different from the 'real' wind farm. The question is: will the controller still perform in this situation?

Two tasks, which can be deduced from the above are:
1) Validation of the in Delft developed control oriented wind farm model.
2) Replacing the simulation model in the previously developed control framework with PALM, the high fidelity wind farm model employed in ForWind.

Research Undertaken

Before starting the exchange period, I installed and got myself familiar with the high fidelity wind farm model PALM. Due to this, I could directly start asking questions regarding the PALM model, and was I able to, after obtaining the correct input files, perform proper simulations myself. The PALM simulation data is used for validating the WFSim model. Figure 1 depicts a comparison between power signals computed with PALM and with the WFSim model.

IPID4all Doctorate Research Exchange with Carl von Ossietzky University
Feedback report
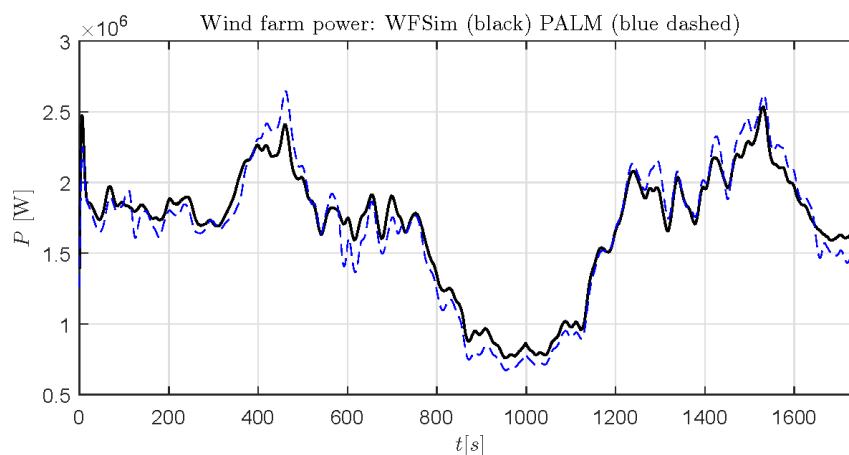
Figuur 1: Comparison of wind farm power signals from a two turbine farm.

From the results, it can be concluded that the WFSim model is able to also estimate PALM data in a fraction of the computation time needed by PALM. Clearly, the stochastic behaviour in the power signals computed by PALM is not present in the WFSim power signals. This is due to model assumptions as discussed previously. However, it is important that the WFSim model is estimating the PALM data, which is clearly the case. A subsequent question is if the estimation is sufficient such that the model can be used in wind farm control. In order to answer this question, first communication and synchronization between the in Matlab written controller (with WFSim model) and PALM (written in Fortran) had to be established. During my exchange period we manged to setup this connection meaning that we are able to read measurements from the PALM model and send these measurements to Matlab. The latter uses these measurements to start up the controller and to compute control signals, which are send to PALM again. This sequence repeats itself during the simulation time.

The communication was a relatively big building block for the proposed setup and this work has been finished. Ongoing work is programming the existing controller in the developed communication protocol. Since both are now in Matlab languages, this should not be an issue. Since during my exchange this task has not been finished, we cannot answer yet the question if the WFSim model in combination with the adjoint model predictive controller can be regarded as a real wind farm controller. Future work will provide answers to this question.

Personal Experience
I worked one month in the ForWind lab and had a pleasant time. The working environment is good and colleagues are friendly and open for questions. I learned working better with and understanding of PALM and hopefully will be able to use this knowledge for my own research.
Although I think we could have made more progress during my stay, I am still satisfied with the steps we made leading us in the right direction.

Conclusions
I think that my one month stay in Oldenburg was successful. I met interesting scientist from a different field and improved my skills to set up PALM simulations. The model developed in Delft has been validated again during my stay, making it a more serious control oriented model. I hope that other researchers will use the WFSim model because we were able to validate it with more high fidelity wind farm data. I also think that the gained knowledge can be used in my thesis work. I just have to figure out how to fit it in my PhD thesis, something I will work on in the near future.

IPID4all Doctorate Research Exchange with Carl von Ossietzky University
Feedback report

Outlook

- We agreed on making two journal papers. One from the work done so far and one in which the simulation model will be replaced by PALM while applying the same controller. The latter task needs more work, but leaps in the right direction were taken during my stay.
- There is no co-supervision planned of the host supervisor.
- Since the IPID4ALL programme finished, no future visits are planned via this programme. Visits via other routes are not planned as well.
- During my stay I talked quite a substantial time with researcher who work on high fidelity models. This field is out of the scope of my background and thesis, but I think it was very interesting to talk and discuss with these researchers. The provided me very valuable information, which I might be able to use in my own thesis.