Project title	Stochastic Model Predictive Control of Wind Turbines: Extension
Project number	TG1-1
Organisation	Chalmers University of Technology, Signals and Systems
Project leader	Professor Bo Egardt
Other participants	Alexander Stotsky (Researcher)
Report for	2011-01-01 – 2013-10-30
Participating companies	ABB, Göteborg Energi, GE, WindVector

Project description

New stochastic model predictive turbine control strategies based on upwind velocity and direction measurements and load measurements were developed within the project TG1-1 *Stochastic Model Predictive Control of Wind Turbines.* These strategies allow (1) mitigation of turbine loads at high wind speeds; (2) more precise regulation close to limits that has the additional potential of improving turbine efficiency at high wind speeds.

Results

The results show potential load reduction and turbine power output improvement due to availability of the wind speed preview information, provided by the laser wind speed measurement system (LIDAR). Look-ahead calculations, constraints on blade loads, robust drivetrain controllers, improvements of the pitch transients as well as post-processing techniques for estimation of the turbine parameters were key elements of the new proactive control concepts developed within this project. A new turbine model validation technique that was based on adaptation of look-up tables was also developed. Simulation results from the VIDYN turbine simulation program and measurements from Big Glenn wind turbine, located outside Gothenburg were used as an input to this new model validation technique. The models of the flapwise bending moment and power coefficient were validated for Big Glenn turbine. Measurement data were acquired during normal turbine operation. Verification results showed good agreement between model outputs and measured data. The method allowed prediction in a wide range of turbine operating variables, using only few measured points. Validated models were simple enough to be used for control design and simulations.

Six journal papers have been published within this project [1] - [6]. Four papers were presented on the reputable IFAC and IEEE conferences [7] - [10].

Fulfilment of SWPTC's goals

The project contributes to the following SWPTC goals:

- General build-up of a turbine modelling know-how that will eventually facilitate high-quality training of engineers in wind power area
- High-class research aimed at achieving optimal operation of wind turbines
- Increase of the turbine life time due to better load and power modelling and predictions
- Publications in respected international scientific journals and presentations at reputable international conferences

Deviations from project plan

The deviations from the project plan were minor.

Publications

Journal Papers

1. A. Stotsky, *Wind Turbine Model Validation: Fusion of Simulation and Measurement Data*, Proc. IMechE Part I: Journal of Systems and Control Engineering, vol. 228, N 9, 2014, pp. 734-737.
2. A. Stotsky, B. Egardt, O. Carlson, *An Overview of Proactive Wind Turbine Control*, Energy Science and Engineering, N 1, 2013, pp. 1-10.
3. A. Stotsky, B. Egardt, *Data-Driven Estimation of the Inertia Moment of Wind Turbines: A New Ice Detection Algorithm*, Proc. IMechE Part I: Journal of Systems and Control Engineering, vol. 227, N 6, 2013, pp. 552-555

4. A. Stotsky, B. Egardt, *Individual Pitch Control of Wind Turbines*: Model-Based Approach, Proc. IMechE Part I: Journal of Systems and Control Engineering, vol. 227, N 7, 2013, pp. 602-609.
5. A. Stotsky, B. Egardt, *Model Based Control of Wind Turbines: Look-Ahead Approach*, Proc. IMechE Part I: Journal of Systems and Control Engineering, vol. 226, N 8, 2012, pp. 1029-1038.
6. A. Stotsky, B. Egardt, *Proactive Control of Wind Turbine with Blade Load Constraints*, Proc. IMechE Part I: Journal of Systems and Control Engineering, vol. 226, N 7, 2012, pp. 985-993.

Conference Papers

7. A. Stotsky, *Wind Turbine Model Validation: Fusion of Simulation and Measurement Data*, 19-th IFAC Congress, Cape town, South Africa, August 22-29, 2014, pp. 3629-3632.
8. A. Stotsky, B. Egardt, O. Carlson, *Control of Wind Turbines: A Tutorial on Proactive Perspectives*, 2013 American Control Conference (ACC), Washington DC, USA, June 17-19, 2013, pp. 3435-3442.
9. A. Stotsky, B. Egardt, *Robust Proactive Control of Wind Turbines with Reduced Blade Pitch Actuation*, IFAC Multi-Conference on Systems Structure and Control, Grenoble, France, February 4-6, 2013, pp. 690-695.
10. A. Stotsky, B. Egardt, *Model Based Control of Wind Turbines: Look-Ahead Approach*, 7-th IFAC Symposium on Robust Control Design, Aalborg, Denmark, June 20-22, 2012, pp. 639-646.

External activities

- Stotsky participated and presented a paper at the 19-th IFAC Congress, Cape town, South Africa, August 22-29, 2014.
- A. Stotsky participated and presented a paper at the 2013 American Control Conference (ACC) in Washington DC, USA, June 17-19, 2013.
- Stotsky participated and presented a paper at the IFAC Multi-Conference on Systems Structure and Control, Grenoble, France, February 4-6, 2013.
- Stotsky participated at the conferences “Vindkraftforskning i fokus” at Chalmers, and contributed with posters and a presentations (2012, 2013).
- Stotsky organized and participated in the VIDYN training course given by
- Teknikgruppen and Scandinavian Wind AB (February – June, 2013). The training was successful and attracted a number of participants from Mechanical and Control Engineering Departments. The participants gained a valuable practical experience, when using VIDYN for turbine simulations. In addition, advantages and limitations of VIDYN simulation platform were identified and discussed openly in this training course.
- Dr. David Schlipf from the University of Stuttgart, Germany visited the Control Engineering Department and SWPTC and gave a talk on LIDAR-enabled wind turbine control (September 2013).
- Professor Rafal Wisnievski from the University of Aalborg, Denmark visited the Control Engineering Department and SWPTC and gave a talk on proactive wind turbine control (September 2012).
- Stotsky participated and presented a paper at the7-th IFAC Symposium on Robust Control Design, Aalborg, Denmark, June 20-22, 2012.