DISTRIBUTED CONTROL OF LARGE SCALE OFF-SHORE WIND FARMS

Aeolus

Mission Statement

A key socio-economic challenge for Europe is: how to deal with a climate change, while meeting rapidly increasing demand for energy and ensuring security of supply? Wind energy can be a significant part of the answer. The new frontier of the wind industry is large-scale offshore wind farms. Now sets of independently operated turbines are combined to supply a reliable resource to the grid. The issue with this is that in reality, the turbines are not operating independently, rather they are inextricably aerodynamically and financially linked via a shared resource with the collection of power from one turbine necessarily implying either a reduction in the power from another or an increase in the load it sees. Wind farms have not previously been studied previously as a control object. The main challenges are the models necessary to describe the interdependencies through the shared resource, the wind, the scale and the distributed nature of the problem.

Inspired by the industrial case of complex large-scale distributed offshore wind farms, the Aeolus project research and develop models of the wakes generated by upwind turbines by physical and data-driven modelling. Experiments are carried out the collect the necessary data from the spatially distributed wind turbine generators. In Aeolus models of the flow information is used as a basis for new control designs, centralized and distributed that dynamically manages the flow resource in order to optimise wind farm control objectives related to power production but also fatigue. The aim is to achieve not the maximum power, but the requested total power at minimal cost. In renewable energy cost links directly to fatigue on key components. The usefulness of our techniques will be validated on a simulated case study and to the extend possible on a physical commercial multi mega-watt wind farm.

Contract number

224548

Project coordinator

Aalborg University

Contact person

Thomas Bak

Aalborg University

Fredrik Bajers Vej 7C

DK-9220 Aalborg

Tel: +45 9640 8701

tba@es.aau.dk

Project website

www.ict-aeolus.eu

Community contribution to the project

2.5 Mio Euro

Project start date

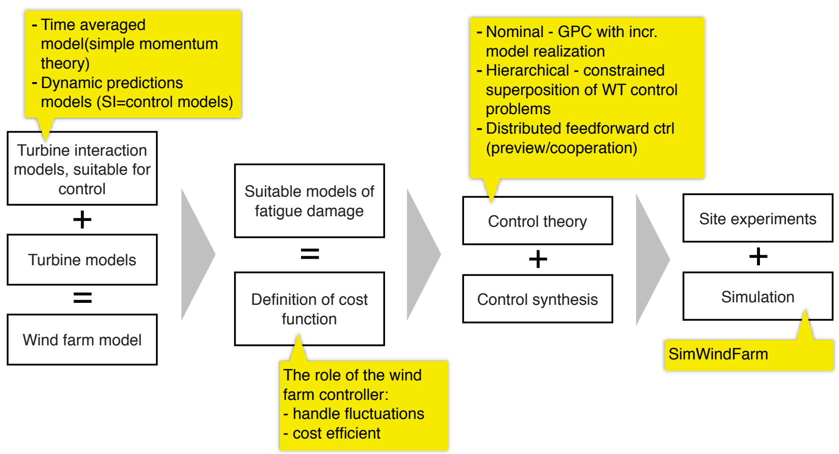
01 05 2008

Duration

41 months

The technical approach

Aeolus study turbine interaction models, developed via physical modeling and data-driven approaches. Together with turbine models the result is models that describe the wind farm system as the plant to be controlled. Next challenge is the definition of suitable models of fatigue damage, leading to cost function definitions. Control theory is developed and applied to the combined plant under the specified cost functions and results are analyzed in simulation and though site experiments. Site experiments on commercial mega-watt wind farms, also link back to the turbine interaction models in relation to the data-driven modeling.



Demonstration and Use

All concepts and components developed within the Aeolus project are demonstrated and validated though simulated experimentation and via site experimentation on a multi mega-watt commercial wind farm. Experiments are carried out on a number of commercial farms to give an indication of the generality of the results. Site experimentation of closed loop control has not been possible due to limitations in current SCADA systems and wind conditions. The experiments do however confirm the effect of changes in loading of upwind turbines, in terms of modifying the wake and the wake changes have been capture in models. The control systems designs have been verified and compared in a simulated benchmark system, called SimWindFarm, which also provides a more general access for the control community to the wind farm control problem. The simulator is implemented in Simulink, which allows easy verification of control synthesis. The benchmark simulator is freely available on the project website and include generic turbine models which can be replaced by whatever wind turbines are relevant for a specific problem.

Project partners	Country
Aalborg University	DK
ISC Ltd.	UK
Lund University	SE
University of Zagreb	CR
ECN	NL
Vestas Wind Systems	DK

Scientific, Economic and societal Impact

For the first time, the Aeolus project has shown, both in simulation and from full-scale test, the potential gains that can be exploited in the area of wind farm control. This will have impact in two arenas – academic and industrial.

In academia, further studies are motivated into: more advanced computational fluid dynamics models for simulation; the development of relevant low-order models for control system design; further distributed and decentralized controllers designed to suit the structure of the problem.

In industry, it is likely the advantage of a cost-of-energy reduction in return for a simple software change is likely to outweigh the disadvantage of paying for more advanced power plant processors. This industrial uptake of the Aeolus work will be facilitated by the simulation tools and fast synthesis environments developed. An interesting extension might be to exploit these tools to safely facilitate more mega-Wattage of wind turbine per square metre and thereby extract more from agreed sites. With extremely long lead times on development projects this could become increasingly attractive.

Despite the Aeolus project's main focus relating to control, a number of work packages pushed research boundaries into modelling wakes. The more accurately wakes can be modelled, the more accurately turbine loads can be predicted and the smaller the safety factors on components need to be. This tends to lead to leaner designs with cheaper profit margins. The developed models may be some way from achieving this, but they certainly provide a first step.

By combining input from world-class academic researchers with the industry leader in wind, we feel this vision for the operation of future wind farms to be interesting and realisable.