UpWind

SIXTH FRAMEWORK PROGRAMME

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WP MEMBERS:

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- Institut für Solare Energieversorgungstechnik e.V. (ISET)
- Energy Research Centre of the Netherlands (ECN)
- Ecotècnia
- Fundación CENER - CIEMAT
- LM Glasfiber A.S.
- GE Global Research
- REpower Systems AG
- Risø National Laboratory – Technical University of Denmark (DTU)
- Gamesa Innovation & Technology

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Control Systems

THE CHALLENGE

To achieve further improvements in the cost-effectiveness of wind turbines, designers are aiming towards larger, lighter, more flexible structures, in which more 'intelligent' control systems play an important part in actively reducing the applied structural loads. This strategy of "brain over brawn" will therefore avoid the need for wind turbines to simply withstand the full force of the applied loads through the use of stronger, heavier and therefore more expensive structures. To reach this point it is now necessary to demonstrate these load reductions in full-scale field tests on a well-instrumented turbine. These control techniques can then be used with more confidence in the design of new, larger and innovative turbines, which are to be studied in this project.

As the penetration of wind energy increases, real issues are already arising relating to the control of the electrical network and its interaction with wind farms. These issues must be resolved before the penetration of wind power can increase further.

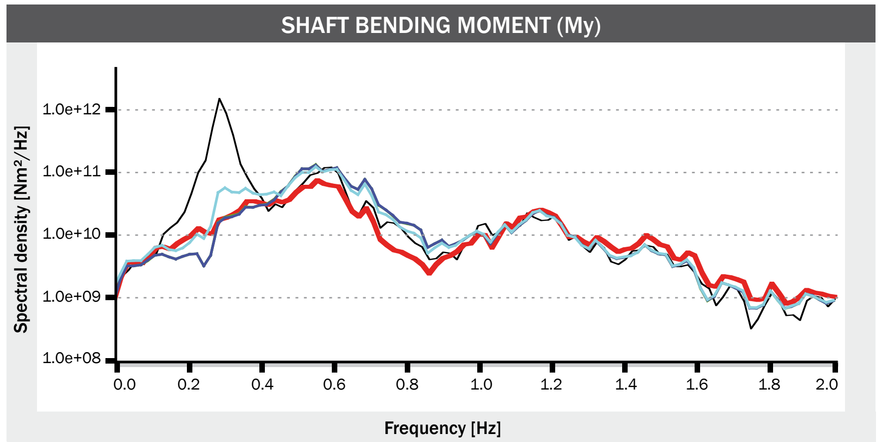
There are three main areas/objectives of work within the work package (WP):

1. Further development of control systems for achieving reductions in wind turbine loads. This includes the sensors and actuators which are required and development of algorithms for estimation of unmeasured loads, as well as further development of the control algorithms themselves. For the algorithms to be effective, efficient methods of adjusting and testing controllers are also being developed. The application of these techniques to new larger and innovative turbines is also an important aspect of the work.

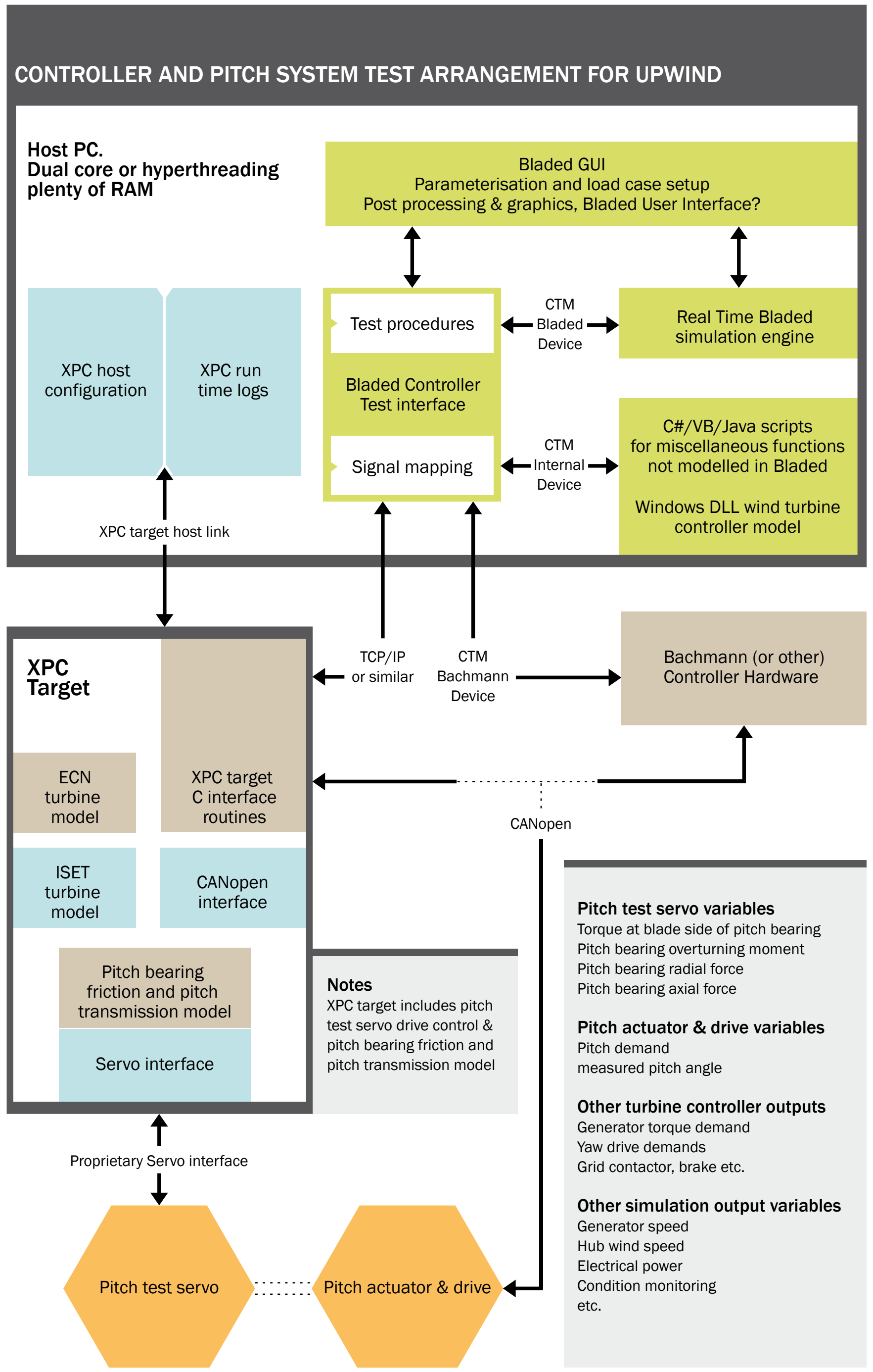
2. Field tests on a commercial turbine to demonstrate that the expected load reductions can be achieved reliably in practice. This is important so that future designs can confidently be optimised to take advantage of these techniques in arriving at improved overall cost-effectiveness.

3. Development of wind turbine and wind farm control techniques aimed at increasing the acceptable penetration of wind energy, by allowing wind turbines to ride through network disturbances, and to contribute to voltage and frequency stability and overall reliability of the network.

UpWind



This figure illustrates the dramatic reduction in the 1P (once-per-revolution) loading peak seen in conventional machines (black line) when individual pitch control is used (coloured lines). The fatigue load reduction can be as much as 40% in some cases.



THE RESEARCH ACTIVITIES

There are three main types of research in the WP.

1. Theoretical research making use of existing analytical models. This research covers a number of different areas, and includes the development of new algorithms as well as the testing of these algorithms using simulation models representing the reference wind turbine designs being used as part of the UpWind project. Topics include:

(a) Further possibilities for load reduction;
(b) Load estimation algorithms;
(c) System identification methods to determine the true dynamic response of a turbine, thereby allowing the controller tuning to be adjusted if necessary;
(d) Possibilities for automated fine-tuning of particular control loops;
(e) Feasibility of dual-control blades with an additional pitch actuator at partial span;
(f) Distributed control of advanced blades whose aerodynamic properties can be varied along the span;
(g) Control for offshore turbines on very soft support structures;
(h) Control for very large turbines (up to 20MW rating);
(i) Adjustments of high wind shutdown strategies to improve wind farm output predictability.

2. Development of testing tools, in particular using hardware-in-the-loop methods to allow subsystems of the controller to be tested in conjunction with a simulated wind turbine. In particular a test setup is being developed in which real turbine controller and/or pitch actuator hardware is interfaced to a real-time simulation of the remainder of the turbine. This allows the detailed functioning of the hardware to be tested easily and repeatably in the laboratory in any simulated environmental conditions, including conditions such as extreme gusts which one would be very unlikely to experience during field tests. This setup is then easily extended to allow other hardware components to be tested, such as generators, yaw drives, etc.

3. Experimental field testing to validate theoretical models. This includes:

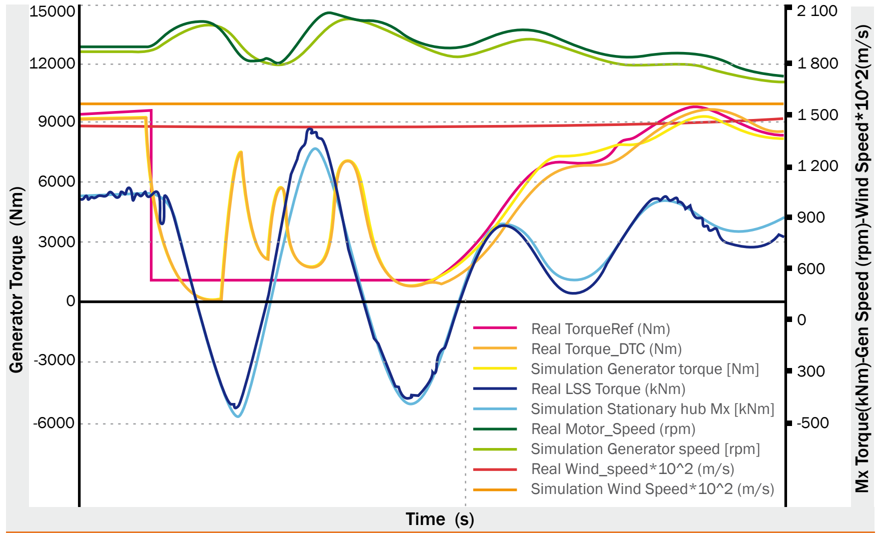
(a) Validation of the significant load reduction potential of individual pitch control which has already been demonstrated in simulations, by implementing and testing the control algorithms on a full-scale commercial turbine;

(b) Validation of electrical transient models of the turbine generator and power converter coupled to a full wind turbine simulation, by comparison against existing field test results which include network voltage dips.

RESULTS AND EXPECTATIONS

This work package is still in progress, and although it is too early to report significant conclusions there are a few findings which can already be mentioned:

- The work on load estimation algorithms has so far focused on the case of tower bending estimation from measured accelerations and is beginning to show some promising results;
- There are also some promising early results on closed loop system identification using measurements from a turbine in closed loop operation to estimate a plant model suitable for tuning of a drive train damper algorithm. Initial work has used data from Bladed simulations, but if successful the method should also be applicable to real turbines;



Comparison of measured and simulated response to a large dip in network voltage.

- A controllability matrix has been derived from a model of a turbine with dual-control blades. Analysis of this has demonstrated that torque and thrust are closely coupled, irrespective of the spanwise position of the second actuator. This means that to decouple the control of torque and thrust is barely feasible, and this concept therefore appears not to be worth pursuing further;
- Many elements of the hardware test facility are already available in the form of the pitch actuator test rig at ISET, the GH Bladed hardware test interface, and simulation software at ECN which has now been extended with thermal models of components to provide realistic temperature input signals for the controller. These elements will be brought together in 2008, and a series of test cases developed to demonstrate the capabilities and the usefulness of the system;
- A fibre-optic sensor system to be used as input for an individual pitch control algorithm is being mounted on a test turbine for detailed evaluation, prior to using such a system for the experimental field testing of the individual pitch controller.