Title: Metrology for wind turbine blade performance

Abstract

Wind turbine manufacturers and designers need access to detailed data relating to the performance of in service wind turbine blades. Currently there is no system available which can directly measure the position of selected points on an operational wind turbine blade. Finite element analysis and other predictive analytical techniques are currently used to calculate the theoretical position of points of interest on the blade surface.

A system to track the motion of the tips of the blades would be a valuable additional tool for blade and turbine designers and has additional applications in failure mode analysis and condition monitoring of blades. Turbine manufacturers have expressed a particular interest in accurate measurement of blade angle of attack at various points along an operational blade.

New structured surfaces are required to reduce drag on the blades and provide immunity to icing and insect accretion. Such surfaces need to be characterised and performance assessed, the objective being to integrate such knowledge into existing system and component designs and models.

Conformity with the Work Programme

This Call for JRPs conforms to the EMRP Outline 2008, section on “Grand Challenges” related to Energy and Environment on pages 8 and 23.

Keywords

Wind turbine blade, deflection measurement, tip tracking, blade design, resistance to aerosols, de-icing, wing shape, micro and nanostructured surfaces.

Background to the Metrological Challenges

The wind turbine industry has grown rapidly over the past twenty years and further growth is expected. The 2011 report by the European wind energy Association, “EU Energy Policy to 2050” [1] predicts the installed wind generation capacity to rise from 75 GW in 2010 to 225 GW in 2020, when wind power will supply 14 % of the EU’s electricity needs. The projection for 2050 is for a further doubling of capacity. The sector has grown by importing components, materials and manufacturing processes from traditional industries, primarily aerospace and gas turbine energy generation. This strategy has caused a number of problems in that the operational environment is quite different and there have been a number of significant failures.

Turbine blade tip tracking

Measuring operating wind turbines in order to verify design assumptions with respect to structural loading is of critical importance, in order to determine structural properties of the wind turbine structure for design improvement, to understand the links between fatigue and blade lifetime, and to estimate lifetime consumption. This is of particular interest for difficult to access offshore wind turbines as their structural behaviour is more complex and difficult to assess than land based machines.

The ability to measure angle of attack while a blade is operating would be extremely valuable to blade designers as it would allow the blade aerodynamic profile to be optimised at each position along the blade length. The ability to record high positional accuracy at various positions on the wind turbine blade including the tips is challenging as the tips can be moving at over 200 miles per hour. The optimisation of the aerodynamic profile would lead to greater efficiency (improved wind energy extraction) and less blade generated noise.

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EMRP
European Metrology Research Programme
Programme of EURAMET

The EMRP is jointly funded by the EMRP participating countries within EURAMET and the European Union

Developing remote sensing measuring and evaluation systems is of particular interest for offshore wind applications. Analysis of this behaviour requires data collection and processing, however sensors utilised for this purpose often have a limited lifetime and can prove costly. Optical measurement techniques can provide a useful analytical technique that negates the need for such costly intervention to establish a greater understanding of wind turbine activity.

Currently during factory tests, a real-time digital video monitoring system captures the motion of the tip of the blade, providing instantaneous feed-back on the motions that the blade is undergoing in the test. A digital video camera captures the image of a target attached to the tip of the blade. The field of view of the camera is calibrated to equate each pixel to a known distance enabling each to be assigned x and y co-ordinates. Various optical laser measurement techniques have been previously tested for the offshore wind sector in the Netherlands. A data processing technique utilised is the Least Square Complex Exponential (LCSE) method for Operational Modal Analysis (OMA). This includes laser interferometry with a Laser Doppler Vibrometer (LDV) and photogrammetry. To test the suitability various wind turbine trials have been undertaken at the ECN test site in the Netherlands. The measuring results indicate that LDV measurements in combination with OMA techniques can be used to identify natural frequencies and damping ratios of wind turbines.

Turbine blade surface properties

Large turbine blades have large surface areas which can result in high drag forces, so surface enhancements of both moulds and blades are currently being developed which will require new metrology techniques, including modelling of air flows, to define and evaluate the surface detail and correlate this with improved aerodynamic performance. A detailed understanding of surface features and the relationship between surface geometry and boundary layer behaviour would facilitate the design of new blades with greater efficiency at high wind speeds, reduced loads on the turbine structure and potentially improved cut-in performance at low wind speeds.

Icing is an issue affecting a large number of existing installations, particularly in northern Europe. Ice can increase the weight of a turbine blade by hundreds of kilograms. Where generation is allowed to continue, imbalances can add an additional load on the drive train. Ice resistant coatings are not yet available and the industry relies on ice detection and warm air blowing. More usually, turbines are switched off, with obvious economic impacts. In some locations, icing reduces annual energy production by as much as 10 %. In humid areas, insect accretion can be just as significant an issue.

Intensive work on the development of new hydrophobic coatings has begun, but not yet delivered results. The aerospace industry is investigating functional surfaces for new smart wing designs; however, no development route for transferring this technology to the wind sector at an appropriate cost and performance has been established. There is also a need to develop an effective measurement technique and standard to quantify ice resistance and how resistant the surface of the blade is to aerosols and rejection of ice.

Scientific and Technological Objectives

Proposers should address the objectives stated below, which are based on the PRT submissions. Proposers may identify amendments to the objectives or choose to address a subset of them in order to maximise the overall impact, or address budgetary or scientific / technical constraints, but the reasons for this should be clearly stated in the JRP-Protocol.

The JRP shall focus on the traceable measurement and characterisation of wind turbine blades.

The specific objectives are

1. To develop a system that can measure the real time deflection of targeted points on wind turbine blades during operation in the field. This should include the ability to measure the angle of attack whilst the blade is in operation to enable the optimisation of the aerodynamic profile of the blade and improved efficiency.
2. To quantify surface properties of the surface of wind turbine blades and to identify methodologies, profiles, surface properties and treatments to improve the efficiency of the turbine
    - To quantify the wear resistance to aerosols of wing surfaces, including (surface) material properties, and to identify new coatings and materials with improved properties.
    - To quantify the ability of wing surfaces to reject ice and dirt and to identify new surface structures and materials with improved properties.

- To correlate and quantify the shape of the wing and the surface structure with wind tunnel measurements and models of the aerodynamic properties of the blades.
- To evaluate and quantify the effectiveness of new micro- and nanostructured surfaces, including biomimetic surfaces, designed to better control the air flows over the wing.

These objectives will require large-scale approaches that are beyond the capabilities of single National Metrology Institutes and Designated Institutes. To enhance the impact of the R&D work, the involvement of the user community such as industry, and standardisation and regulatory bodies, as appropriate, is strongly recommended.

Proposers should establish the current state of the art, and explain how their proposed project goes beyond this.

EURAMET expects the average size of JRPs in this call to be between 3.0 to 3.5 M€, and has defined an upper limit of 5 M€ for any project. The available budget for integral Research Excellence Grants is 30 months of effort.

Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the “end user” community. This may be through the inclusion of unfunded JRP partners or collaborators, or by including links to industrial/policy advisory committees, standards committees or other bodies. Evidence of support from the “end user” community (eg letters of support) is encouraged.

You should detail how your JRP results are going to:

- feed into the development of urgent documentary standards through appropriate standards bodies
- transfer knowledge to the wind turbine manufacturers, wind energy generation sector.

You should detail other impacts of your proposed JRP as detailed in the document “Guide 4: Writing a Joint Research Project”

You should also detail how your approach to realising the objectives will further the aim of the EMRP to develop a coherent approach at the European level in the field of metrology and includes the best available contributions from across the metrology community. Specifically the opportunities for:

- improvement of the efficiency of use of available resources to better meet metrological needs and to assure the traceability of national standards
- the metrology capacity of Member States and countries associated with the Seventh Framework Programme whose metrology programmes are at an early stage of development to be increased
- outside researchers & research organisations other than NMIs and DIs to be involved in the work

Time-scale

The project should be of up to 3 years duration.

Additional information

The references were provided by PRT submitters; proposers should therefore establish the relevance of any references.

[1] EU Energy Policy to 2050, Report by the European Wind Energy Association, March 2011, http://www.ewea.org/fileadmin/ewea_documents/documents/publications/reports/EWEA_EU_Energy_Policy_to_2050.pdf