TITLE: Metrology for Wind Energy Conversion

Abstract

The European Union's Renewable Energy Directive 2009/28/EC [1] represents a new driving force for the development of a metrological infrastructure to support the renewable energy sector. The vision of providing 23 % European electricity by wind by 2030 [2] is a challenging one, but many European countries have built (or are planning) wind farms. Currently energy generation from wind is far from optimised, since the best wind farms only capture around 36 % of the available wind energy. It is therefore essential that design and efficiency are optimised now.

Many aspects of wind turbines have the potential to be improved including: aerodynamic properties of rotor blades, gearbox longevity, and performance at high and low wind speeds. In addition, reliable energy production requires traceable wind speed measurements with low uncertainties.

Joint Research Projects (JRPs) submitted for this topic should develop traceable measurement techniques (and data) to support improvements in wind turbine design, and in the measurement of wind turbine efficiency (such as accurate wind speed measurement)

Conformity with the Work Programme

This Call for JRPs conforms to the EMRP 2008 [3] section on "*Grand Challenges"* related to *Energy* on page 23.

Keywords

Air speed, blade surface texture, dimensional metrology, gear optimisation, friction, high-powered wind turbines, measurement of wind conditions, mechanical metrology, remote sensing, turbine efficiency, turbine stability, traceable wind speed measurement, wind power, wind turbine, windmill.

Background to the Metrological Challenges

Wind power is one of the few renewable energy sources capable of rapidly satisfying a reasonable proportion of future energy requirements. In 2006, the European Wind Energy Platform Technology Advisory council laid out a vision [2] for 2030, in which 23% of the electricity consumption in the EU is supplied from wind energy.

At present wind turbine technology is in its relative infancy. Much of the engineering has been simply scaled-up from conventional scales. Commercial wind turbines are currently specified at a capacity of around 9 W/m^2 energy generation for a typical 1 MW turbine [4]. However, the average load factor of around 30% means that they rarely achieve more than 3 W/m^2 actual output. This is due to inability to work at high and low wind speeds (safety and frictional/efficiency effects) and the available wind levels at typical sites. If wind energy is to supply a greater proportion of future renewable energy supplies, the efficiency and average load factors need to be improved. This will require: longer life design, scaling up of rotor size, improved bearing design, optimisation for deep offshore installation, reduction of frictional effects, advanced aerodynamic design for larger rotor tip-noise reduction, improvement in safety and remote monitoring. All of these will require many metrology issues to be addressed.

The best investment in wind energy is therefore to plan to build big farms with large rotors in windy locations, to optimise the energy capture efficiency and to address longevity and safety concerns.

Currently, the state-of-the-art linear models do not adequately accommodate the complexity of local wind conditions. Highly resolved, accurate and traceable measurements of the wind speed, including those produced by remote sensing techniques, will lead to a reduction in the uncertainties of wind resource assessment models.

It is considered that applied metrology research and development would have a positive impact on the feasibility of mass wind harvesting in the following areas:

Scaling up and other ways to access faster velocity wind
Turbine power scales with kinetic energy density of the air flow over the rotor as the cube of the velocity. Wind velocity increases with altitude. Therefore, larger diameter wind-turbines justify larger support structures in order to access higher winds. However, manufacturing of larger structures requires better metrology in terms of supports, rotors, bearings and the alignment of the various items.

Bearing and blade optimisation
Wind turbines now use some of the largest bearings available. New types of bearings will require new metrology techniques for measurement of shape to ensure proper alignment and optimisation. Surface defects will start small but rapidly evolve into major sources of inefficiency or failure, when the large forces act for any length of time.

Novel blade designs for higher efficiency and reliability will require new metrology in order to reduce the test cycle times, underpin aerodynamic improvements and avoid aero-elastic instabilities.

Wind conditions, wind speed
Limitations of traditional wind measurements at large heights have raised interest in remote sensing techniques applied to the wind energy sector. Commercial LIDAR systems for wind resource assessment entered the market in 2007. These systems enable remote sensing of vertical wind profiles in heights between 0 m and 150 m with an accuracy and a reproducibility partly comparable to profile data obtained with cup anemometers. Of increasing relevance are LIDAR technologies, especially for wind resource assessment and power curve evaluation, where standards will have to be developed in order to ensure the traceability of LIDAR wind speed measurements.

Scientific and Technological Objectives

Proposers should aim to address all of the stated objectives below. However where this is not feasible (i.e. due to budgetary or scientific / technical constraints) this should be clearly stated in the JRP protocol. The objectives are based around the PRT submissions. As experts in the field, JRP proposers should establish the current state of the art, which may lead to amendments to the objectives - these should be justified in the JRP proposal.

The objectives are:

- development of improved measurement techniques for wind speed, field and profile including remote sensing techniques and modelling
- dimensional characterisation and force/torque measurement of power transmission components to reduce risk of gearbox failures
- characterisation of blade features and optimisation of flow properties for reduction of energy losses
- metrological contributions to optimize operation at high and low wind speeds (safety and frictional/efficiency effects)

The generation/reduction of noise as a topic of its own is not being considered as in the scope of TP “Metrology for energy”.

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.

Where a European Directive is referenced in the proposal, the relevant paragraphs of the Directive identifying the need for the project should be quoted and referenced. It is not sufficient to quote the entire Directive per se as the rationale for the metrology need. Proposals must also clearly link the identified need in the Directive with the expected outputs from the project.

In your JRP submission please detail the specific impact that your proposed JRP will have on the wind turbine manufacturing and renewable energy planning and supply sector and on the following Directive of the European Commission:

> “Promotion of the use of energy from renewable sources Directive” 2009/28/EC [1]

You should also detail other Impacts of your proposed JRP as detailed in the document “Guidance for writing a JRP”.

You should detail how your JRP results are going to:

- Contribute to the further development of standards for calibration service providers and computational modellers and designers
- Transfer knowledge transfer to the wind turbine manufacturing sector and the professionals involved in the planning of wind farms.

Additional Information

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

[1] Directive 2009/28/EC of the European Parliament and the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:140:0016:0062:EN:PDF

[2] Wind Energy: A Vision for Europe in 2030 http://www.windplatform.eu/fileadmin/ewetp_docs/Structure/061003Vision_final.pdf

[3] European Metrology Research Programme. Outline 2008 Edition - November 2008, http://www.euramet.org/index.php?eID=tx_nawsecuredl&u=0&file=fileadmin/docs/EMRP-outline2008.pdf&t=1248796946&hash=9da9ceb781370f04c322ac48068deca5

[4] http://www.world-nuclear.org/reference/pdf/DTI-PIU.pdf

[5] European Wind Energy Technology Platform, Strategic Research Agenda**,** Market Deployment Strategy, FROM 2008 TO 2030, July 2008

- executive summary
- Annex A: detailed research actions
- Annex B: state-of-the-art and current insufficiencies

[6] EWEA (The European Wind Energy Association): EWEA - 02/2009, wind energy and the job market

For further references, see the indices within http://www.withouthotair.com/.