Title: LIDAR-based remote sensing of wind speed for wind energy farms

Abstract

In the wind energy industry, accepted wind speed measurements based on cup anemometers and measuring masts have reached their limits as recent wind turbines exceed hub heights far above 100 m. This leads to an increasing demand for remote sensing techniques for wind potential studies, resource assessment and power curve measurements. Current approaches to traceable wind LIDAR measurements for resource assessment and power curve measurements are not sufficient, especially in complex terrain. The development of new traceable, high-resolution remote sensing techniques will improve predictions of the annual energy production by advanced models and help to increase the efficiency of wind farms due to advanced power performance measurement capabilities.

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, 23, 37 and 43.

Keywords

Wind speed, remote sensing, wind LIDAR, wind LIDAR calibration, wind resource assessment, power curve measurement, load control, traceability

Background to the Metrological Challenges

As the energy produced by wind energy plants depends on the cube of the wind speed, traceable wind speed data and uncertainties are key parameters for reliable statements of wind resources, power curves, power performance characteristics and estimated annual energy production (AEP) to support decisions in the evaluation of wind farm efficiencies.

The move towards more efficient larger scale wind turbines with hub heights above 100 m has resulted in the well-established wind speed measurements based on measuring mast mounted cup anemometers increasingly being supported by wind LIDAR measurements. For wind LIDAR measurements to be accepted there is a need for suitable procedures and the development of advanced techniques to ensure the traceability of remote wind speed measurements with the lowest possible uncertainties. In practice however these uncertainties are related to mast measurements which in principle do not undercut the cup anemometer combined calibration and mast boom uncertainties. In addition the uncertainties also depend on the wind shear over the terrain and the test field due to the limited local resolution of remote wind sensors. The validation of the computational fluid dynamics (CFD) models used for analysis of the efficiency of wind turbines and wind farms would benefit from a higher local resolution of traceable remote wind speed measurements. The use of nacelle based remote wind sensors to reduce extreme and fatigue loads and to improve energy capture is increasing due to the drive for cost efficiency of wind energy plants, however economic remote sensors with sufficient local resolution are required.

The evaluation of the cost effectiveness of assembling and repowering of wind energy plants is based on the estimated annual energy production (AEP), which is determined according to the procedures in the IEC 61400-12-1 Wind turbines – Part 12-1: Power performance measurements of electricity producing wind turbines [1]. Key parameters are the wind conditions, which usually are obtained by measuring masts equipped with cup anemometers, which are calibrated according to the cup anemometer calibration procedure included in the IEC 61400-12-1. Currently cup anemometer traceable wind speed data are required for accepted wind assessment tasks, power curve and power performance measurements to evaluate and improve the efficiency of wind turbines and wind farms. Since it is expensive and logistically complex to erect masts comparable the hub-height of modern turbines, it is necessary to analyse and improve remote sensing techniques based on the experience with the wind LIDAR systems currently in use.

The remote wind sensing devices commercially available today measure the three wind speed components in spatially separated volumes. This technique has the disadvantage that these systems assume equal wind conditions within the different probe volumes used for the evaluation of the wind speed. This assumption can lead to significant measurement errors especially in complex terrain, thus these errors have to be assessed for every application of a remote sensing system.

It is important to assess LIDAR data in view of the required accuracy for AEP predictions. AEP predictions are not very accurate due to a number of parameters such as the wind measurement, flow modelling of the site, power curve uncertainties to shear and turbulence. Even in flat terrain studies of AEP predictions as compared to actual production have shown large biases, up to 10 % and large uncertainties, with standard deviations above 15 %.

Assessment reports of commercially available conically scanning LIDARs in flat terrain refer to estimated cup traceable uncertainties within 3 %. Lower uncertainties will be limited by the mast-mounted cup anemometers which have combined calibration and mast/boom uncertainties approaching 1.5 % at the test site. In complex terrain the overall uncertainties will increase due to wind shear and turbulence and the low local measurement resolution of commonly used LIDAR systems. To enable accuracies within 3 % hub-height measurements using cup anemometers are currently needed. However this is not always economically or logistically viable. Current cup-traceable wind LIDAR accuracies are likely to provide AEP predictions below ±10 % in flat terrain at hub-heights exceeding 60 m

According to the strategic research agenda of the European Wind Energy Technology Platform [2] an ambitious long term vision of the wind energy industry includes the prediction of the annual energy production with an uncertainty of less than 3%.

In order to reduce uncertainties and deviations further research and development activities enabling traceable wind LIDAR measurements and techniques are required.

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 speed for wind energy generation applications.

The specific objectives are

1. To develop and implement a remote wind sensor standard with traceability realised independently from the conventional cup anemometer traceability, and with uncertainties significantly below those obtained with the existing measuring mast and cup anemometer based traceability. The standard should enable calibrations of commonly used wind LIDARs as well as traceable wind speed measurements in complex terrain without cost-intensive measuring masts.
2. To further develop traceable LIDAR-based remote sensing techniques, including procedures and transfer standards, to provide traceable wind speed, wind field and wind profile measurements for wind resource assessment over different terrains and power curve evaluations.
3. To develop new advanced methods for flow prediction based on CFD methodology modelling methods supported by highly-resolved measurement data from remote sensing techniques, for the verification of wind resource prediction, wind shear, wind veer and turbulence, and for modelling of the effect of neighbouring wind turbines and terrain.
4. To develop techniques for the calibration of nacelle based wind LIDAR systems in order to improve the assessment of performance. The techniques and the remote sensors should be suitable both metrologically and economically for the real world applications.
5. To develop guidelines and recommendations to supplement the recent revision of the IEC 61400-12-1 “Wind turbines”. The aim is to ensure the traceability of wind speed

measurements based on remote sensing techniques with uncertainties that are at least comparable to the well-established measuring mast based cup anemometer traceability but applicable for measurement at heights of up to 200 m even for complex terrain.

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, such as IEC
- transfer knowledge to the wind speed instrumentation manufacturers and the wind generation sector.
- Interact with other initiatives in the field such as the European Technology Platform for Wind Energy [2] and the European Wind Initiative [3]

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] IEC 61400-12-1 Wind turbines - Part 12-1: Power performance measurements of electricity producing wind turbines

[2] European Technology Platform for Wind Energy (TPWind): Strategic Research Agenda, Market Deployment Strategy From 2008 To 2030, http://www.windplatform.eu/home/strategic-research-agenda-market-deployment-strategy/

[3] EWEA: The European Wind Initiative, Wind Power Research and Development to 2020, http://www.ewea.org/fileadmin/files/library/publications/reports/EWI_2013.pdf