EMPIR Call 2019 – Energy, Environment, Normative and Research Potential

Selected Research Topic number: **SRT-g20**
Version: 1.0

Title: Metrology for enhanced reliability and efficiency of wind energy systems

Abstract

With the transition to renewable energies, enhancing the efficiency of one of the most promising sources, wind energy, is essential. The mechanical components of Wind Energy Systems (WES) are exposed to very high loads. For example, torques of up to 20 MNm are transmitted to the gears, shafts and bearings of the drivetrain. The high loads combined with the component's large size and mass result in tight manufacturing tolerances. As a result, reliable metrological verification of these tolerances is a critical part of quality assurance and improved industrial measurement capabilities are urgently required. In addition, the trends, defined by the Manufacturing Metrology Roadmap 2020, for digitalisation and towards industry 4.0 need to be considered.

Keywords

Wind Energy Systems, rotor blades, drivetrain components, digitalisation, optical and multi-sensor systems; high-speed contact scanning, Digital Twin

Background to the Metrological Challenges

The 2020 EU climate and energy package sets the 20/20/20 target rates for reduction of greenhouse gas emissions, share for renewable energy and improvement in energy efficiency. The target rates have been increased to 27 % for share of renewable energy and improvement in energy efficient by 2030. One of the most promising renewable energy sources is wind power. Greater efficiency of this technology can be obtained by enlarging the hub height as well as the rotor diameter, however these lead to higher loads acting on the mechanical parts like turbine blades and drivetrain components. WES breakdowns due to mechanical component failures can cause downtimes of several days. Improving dimensional metrology, for drivetrain components and turbine blades for WES will enable reliable production processes as well as improving the availability, power density and efficiency of WES. EMRP project ENG56 focused on the traceability for measurements of drivetrain components for renewable energy systems. However, more work needs to be done to fulfil the demands of the Manufacturing Metrology Roadmap 2020, published in 2011 by the German VDI/VDE Society for Measurement and Automatic Control (GMA), in terms of an increasing need for digitalisation as well as addressing the requirements of industry 4.0.

Various optical and multi-sensor systems capable of conducting roughness, form, and dimensional measurements of gears and other drivetrain components have been developed. However, in order to improve production control and assure the reliability of ISO 14253 based conformity decisions, the current repeatability and the uncertainty budget needs to be improved and the harsh environments of WES need to be taken into account. High-speed contact scanning is established in tactile coordinate metrology. However, the most accurate results are achieved in single-point measurements. A reliable characterisation of the relation between scanning speed and loss in harmonic content for large components of WES is lacking. In addition, established measurements and evaluation routines defined in international standards, mostly relate to cross sections rather that to the entire workpiece. Evaluation methods need to be developed considering the whole workpiece. Erosion of the leading edge of a turbine blade has a large influence on its efficiency. Inspection using image processing sensors applied on drones is advantageous; however, reliable assessment of the accuracy of such systems is still lacking. The current state-of-the-art is based on qualitative and empirical decisions. A digital twin (DT) of the leading edge could offer an alternative of predicting the degradation of the blade's efficiency. A tighter integration of metrology into production processes, especially by means of machine tool inspection systems, will contribute to faster and more efficient measurement results. EMRP project IND62 studied the traceability of in-process dimensional measurements, and the results offered a sound basis for transfer to machine tools for drivetrain components. Furthermore, self-calibration procedures for rotary axes have been developed but have not been widely tested nor transferred to rotary axes of machine tools.

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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 protocol.

The JRP shall focus on the traceable measurement and characterisation of mechanical components of WES.

The specific objectives are

1. To investigate fast optical and multi-sensor measurement methods for roughness, form, and dimensions of mechanical components of WES and to determine the associated uncertainties. This will include coordinate measuring machines with different sensor systems as well image processing sensors applied on drones for measurements directly at WES.
2. To develop improved measurement and evaluation methods for surface and material properties of industrial drivetrain components using both tactile and contactless sensors including the comparison of high-speed contact scanning with single-point measurements, taking into account harmonic content, and development of algorithms for characterisation of these components in a shop floor environment.
3. To develop a digital twin (DT) of drive-train and turbine blades to predict the degradation in the turbine's efficiency based on 2D or 3D images of blade leading edges, wind tunnel experiments and computational fluid dynamics (CFD). This will include a study into the applicability of Model Based Definition (MBD) for measurement script generation.
4. To evaluate and improve the accuracy of machine tool measuring stations for fast and flexible in-line metrology operating in harsh environments. This will include the development of calibration strategies for in-situ machine measuring systems and an assessment into the feasibility of self-calibration methods for rotary axis calibration.
5. To facilitate the take up of the technology and measurement infrastructure developed in the project by the measurement supply chain, standards developing organisations (e.g. ISO TC 213) and end users (large drivetrain component and turbine blade manufacturers).

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 research, the involvement of the appropriate user community such as industry, standardisation and regulatory bodies is strongly recommended, both prior to and during methodology development.

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

In particular, proposers should outline the achievements of the EMRP or projects ENG56 and IND62 and how their proposal will build on those.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 2.0 M€, and has defined an upper limit of 2.3 M€ for this project.

EURAMET also expects the EU Contribution to the external funded partners to not exceed 35 % of the total EU Contribution across all selected projects in this TP.

Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the "end user" community, describing how the project partners will engage with relevant communities during the project to facilitate knowledge transfer and accelerate the uptake of project outputs. Evidence of support from the "end user" community (e.g. letters of support) is also encouraged.

You should detail how your JRP results are going to:

- Address the SRT objectives and deliver solutions to the documented needs,
- Feed into the development of urgent documentary standards through appropriate standards bodies,
- Transfer knowledge to the wind energy sector.

You should detail other impacts of your proposed JRP as specified in the document "Guide 4: Writing Joint Research Projects (JRPs)"

You should also detail how your approach to realising the objectives will further the aim of EMPIR to develop a coherent approach at the European level in the field of metrology and include 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 EURAMET Member States whose metrology programmes are at an early stage of development to be increased
- 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]. M/087 Standardisation mandate to CEN and CENELEC for standardization in the field of wind turbines

[2] VDI/VDE GMA: Fertigungsmesstechnik 2020 - Technologie-Roadmap für die Messtechnik in der industriellen Produktion. April 2011