# Title: Torque measurement in the MN·m range

## Abstract

Torque is an important quantity for many industrial processes. Even though it is mainly applied in the wide range of kN·m, more and more industrial branches need to measure torques larger than 1 MN·m. One main source of ever growing torque loadings is the development in wind industry. To ensure the reliability of wind turbines and minimise downtime, extensive testing is necessary. Many large test stands (transmission or entire nacelle) have been built or are under construction; but, as yet, no test stand for wind turbines has traceability to national torque standards for large torque loads.

## Keywords

Torque measurement, calibration, traceability, turbine test stand, industrial testing, measurement uncertainty

## Background to the Metrological Challenges

Many European countries have pledged to change their electricity production from carbon emitting power plants to renewable energies, including Germany with a planned 55 - 60 % renewable energy until 2035 [1], Denmark aiming at 42 % wind energy until 2020 [2] and the UK with a target of 15 % renewable energy until 2020 [3]. One main pillar in this new energy mix in most countries is onshore and offshore wind energy; with offshore wind turbines able to provide a predictable and steady electricity flow, which may eventually be used as part of the base load in the electrical grid. To fulfil this important role in energy production, a high reliability of power production is important. Extensive testing of prototype turbines is a main factor to ensure a high reliability and more than ten large test stands have been built, or are under construction, in Europe.

Although tests are necessary to predict the performance over a turbine lifetime, the quality of the test results is only as good as the measurements involved. In the case of large wind turbines, currently torques of more than 10 MN·m can be reached in the transmission; and even larger turbines are already in planning. These torques cannot be traced to any national torque standard because the largest torque standard worldwide is the 1 MN·m Torque Standard Machine (TSM) [4]; and thus not enough to deal with a demand of traceability for torques larger than 10 MN·m. This demand has been identified internationally [5] and it is necessary to enable traceability of large turbine test stands to enhance the development of reliability in the wind energy production by an increased test quality and advancing the change in the energy mix in the European Union.

The demand in wind industry has led to steadily rising electrical power listings of wind turbines from around 1 MW in the 1990s to more than 6 MW at present. In the last two years, several wind turbine test stands have been developed, but these test stands still have no direct torque traceability for their large torque loads > 1 MN·m. There are four different options to deal with this issue: 1) Strain gauges attached to mechanical parts to measure strains and calculate loads from these measurements; 2) In transmission test stands with pure torque loading (e.g. back to back test stands) torques are measured on a faster shaft and using the conversion, the torque load on the slower shaft can be calculated; 3) The electric power of the engine on the load side of the test stand can be measured - with the rotational speed of the loaded shaft, which is better obtainable than the torque load, the corresponding torque load can be calculated; and 4) The product of the offset force is applied to the shaft and the distance to the shaft's central axis is used to calculate the applied torque.

However, all four options have drawbacks: the usage of strain gauges without calibration of the prepared mechanical part is very limited in accuracy because knowledge of the material properties and dimensions is insufficient; measurements at a different part of the transmission line (either electric power or faster shaft) rely on estimations of friction losses in transmission parts (e.g. gears or engines) and the use of the product between force and distance is still inflicted with unknown uncertainties.

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To date, no research has been published on this topic but existing test stands are likely to be calibrated with procedures that may be used to enable traceability assuming a positive outcome of the proposed research topic.

## 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 proposal.

The JRP shall focus on the development of methods to provide traceability up to the multi-MW range for torque measurements for wind turbine test stands, in order to improve the quality of test results and ensure a higher reliability of newly constructed wind turbines.

The specific objectives are

1. To review existing turbine test stands, in particular entire nacelles and their boundary conditions. The review should include the range of loads that can be applied by the machine and the dimensions of the stand, as well as existing methods of calibration and the levels of uncertainty achieved.
2. To develop innovative and traceable calibration methods for torque values in turbine test stands in the form of transfer standards for range above 1MN.m. In order to allow the multi-use of transfer standards a unified approach for test stands should be applied.
3. To investigate the effect of multi-component loading on the measurement of torque. In particular, cross-talk effects in the case of 6-component loading (3 directional force, 2 directional bending, torque).
4. To develop a calibration procedure for large turbine test stands. The calibration procedure should enable the traceability of torque loads up to 20 MN·m and include an uncertainty model that considers cross-talk effects.
5. To engage with industries that utilise multi-MW range for torque measurements to facilitate the take up of the technology and measurement infrastructure developed by the project, to support the development of new, innovative products, thereby enhancing the competitiveness of EU industry.

Proposers shall give priority to work that meets documented industrial needs and include measures to support transfer into industry by cooperation and by standardisation. An active involvement of industrial stakeholders is expected in order to align the project with their needs – both through project steering boards and participation in the research activities.

Proposers should establish the current state of the art, and explain how their proposed project goes beyond this and EMRP JRP SIB63 (Force) ‘Force traceability within the meganewton range’.

EURAMET expects the average EU Contribution for the selected JRPs to be 1.5 M€, and has defined an upper limit of 1.8 M€ for any project.

EURAMET also expects the EU Contribution to the external funded partners to not exceed 30 % of the total EU Contribution to the project. Any deviation from this must be justified.

Any industrial partners that will receive significant benefit from the results of the proposed project are expected to be unfunded partners.

## 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,
- Drive innovation in industrial production and facilitate new or significantly improved products through exploiting top-level metrological technology,
- Improve the competitiveness of EU industry,

- Feed into the development of urgent documentary standards through appropriate standards bodies,
- Transfer knowledge to the wind industry sector.

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

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] “Coalition agreement of CDU and SPD in 2013.” [Online]. Available: http://www.cdu.de/artikel/der-koalitionsvertrag-von-cdu-csu-und-spd. [Accessed: 02-Dec-2013].

[2] “Statement of the Danish Ministry of Climate, Energy and Building according to the Energy Strategy 2050.” [Online]. Available: http://www.kebmin.dk/en/climate-energy-and-building-policy/denmark/energy-supply-and-efficiency/renewable-energy/wind. [Accessed: 17-Jan-2014].

[3] “UK Renewable Energy Roadmap Update 2013.” [Online]. Available: https://www.gov.uk/government/publications/uk-renewable-energy-roadmap-second-update. [Accessed: 17-Jan-2014].

[4] A. Schäfer, “Strain , force and torque measurement in drive trains , blades , towers and foundations of offshore wind turbines (Poster),” in EWEA Offshore 2011, 2011.

[5] PTB, “Force traceability within the meganewton range.” [Online]. Available: http://www.ptb.de/emrp/forcemetrology.html. [Accessed: 20-Jan-2014].