Wind Turbine Tower Structural Health Monitoring

Damages to wind turbine towers cause long downtimes, high costs and possibly serious harm to the surroundings. For this reason, turbine rotation is stopped when winds becomes too strong and towers are serviced at regular intervals. However, there are no established methods to continuously assess the acting forces and to calculate the cumulative stress on the tower over time. This invention provides such a method, based on already available sensor data.

AI assisted continuous calculation of tower-top displacement

IP RIGHTS
International Application Filed
2025

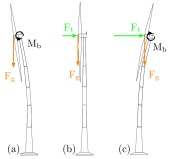
Data from different types of sensors with different standalone accuracies and availabilities are fused using machine learning to provide one combined low-cost continuous measure of nacelle displacement. This measure can be used to monitor both the current stress on the tower and its long-term structural health.

01 Decide on strong-wind shutdowns more reliably based on 3D tower-top displacement instead of wind speed.

02 Increase productive uptime of the generator based on these more reliable data.

03 Enhance remaining useful life estimation and extend the total number of productive hours.

04 Based on existing or easy-to-add sensors, the solution comes at a minimal extra cost.



The forces acting on the wind turbine differ depending on whether it is idle (a) or operating at a partial (b) or high partial to nominal load (c). Moreover, the displacement of the nacelle is influenced by the acting forces.

The invention is currently embodied by a compact prototype module. This module has been operative in a productive wind turbine for several months.

REFERENCES:

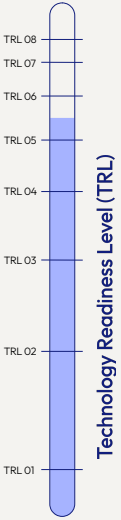
- Pat. appl. WO2026078196A1
- J. Rupfle, dissertation, 2025

CHALLENGE

Strong winds bend and thus strain the wind turbine tower (see figure to the left). Both the instantaneous stress and the cumulative effect over time can in principle be assessed by continuously measuring the 3D displacement of the nacelle, e.g. by using a real-time kinematic positioning (RTK) module based on satellite navigation. However, high-quality RTK data can in practice only be gathered 10-20 % of the time, rendering the entire calculation unreliable.

INNOVATION

To monitor the operation of the wind turbine, a large amount of operating data, such as wind speed and power output, is continuously recorded. These data are somehow correlated to the displacement, but the relation cannot be analytically described. The same is true for acceleration data which can easily be gathered by adding a measurement module. The invention makes use of this connection by training a neural network with RTK data as labels and other data as features when both are available with high quality and subsequently using the network to calculate nacelle displacement when RTK data are unavailable.



01 Basic principles observed · **02** Technology concept formulated · **03** Experimental proof of concept · **04** Technology validated in lab · **05** Technology validated in relevant environment · **06** Technology demonstrated in relevant environment · **07** System prototype demonstrated in operational environment · **08** System complete and qualified

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