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Monitoring system for continuous evaluation of bending moments at the tower of an onshore wind turbine: Calibration and evaluation of alternative approaches

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1 Introduction

The main goal of the recently started WindFarmSHM research project is the development, validation and optimization of a monitoring strategies to be applied at the level of the wind farm, which should be able to evaluate the structural condition of a set of wind turbines and their consumed fatigue life. The accomplishment of this goal implies the development of an experimental campaign involving the simultaneous instrumentation of several wind turbines in the same wind farm. This is being performed in an onshore wind farm with 5 VESTAS V100-1.8 MW wind turbines, with a rotor diameter of 100m, supported by a 93.3m steel tower.
One of the wind turbines is already equipped with accelerometers in 3 sections of the tower, strain gages at two cross sections of the tower, a set of fiber optic strain gages at the blades roots and accelerometers placed at the blades (10 meters from the root). Complementary information about the wind characteristics and the wind turbine operation are obtained from the SCADA system. A detailed description of the monitoring systems and preliminary results can be found in [1].
This work describes alternative approaches for experimental estimation of the bending moments applied in the tower of the already fully instrumented wind turbine.

2 Tower strains and rotations

The monitoring system installed on the tower for forces characterization is composed by 6 2D rosette strain gages, 4 temperature sensors and 3 clinometers connected to central acquisition system, then linked with a modem for remote access to the data. Having in mind the evaluation of the static bending moments diagrams along the tower, the six strain gages are distributed in two tower sections: one with four sensors at 6.6m from the tower base and another section with 2 sensors at 7.8m from the tower base. The temperature sensors and the measurement of the strain in the direction perpendicular to the tower axis are important to evaluate alternative procedures to minimize the temperature influence on the measured longitudinal strains.
The installation of the clinometers aims to measure the rotation at the base of the tower (clinometer 1) and to alternatively estimate the bending moment from curvature derived from the measurement of rotations in two close sections (clinometers 2 and 3). The main advantage of estimating bending moments from rotations is that the installation of the clinometers is less intrusive than the installation of strain gauges (the installation of these involves removing paint from the tower). Clinometer 2 and 3 are spaced 2m, being the section instrumented with 4 strain gages approximately in the middle.

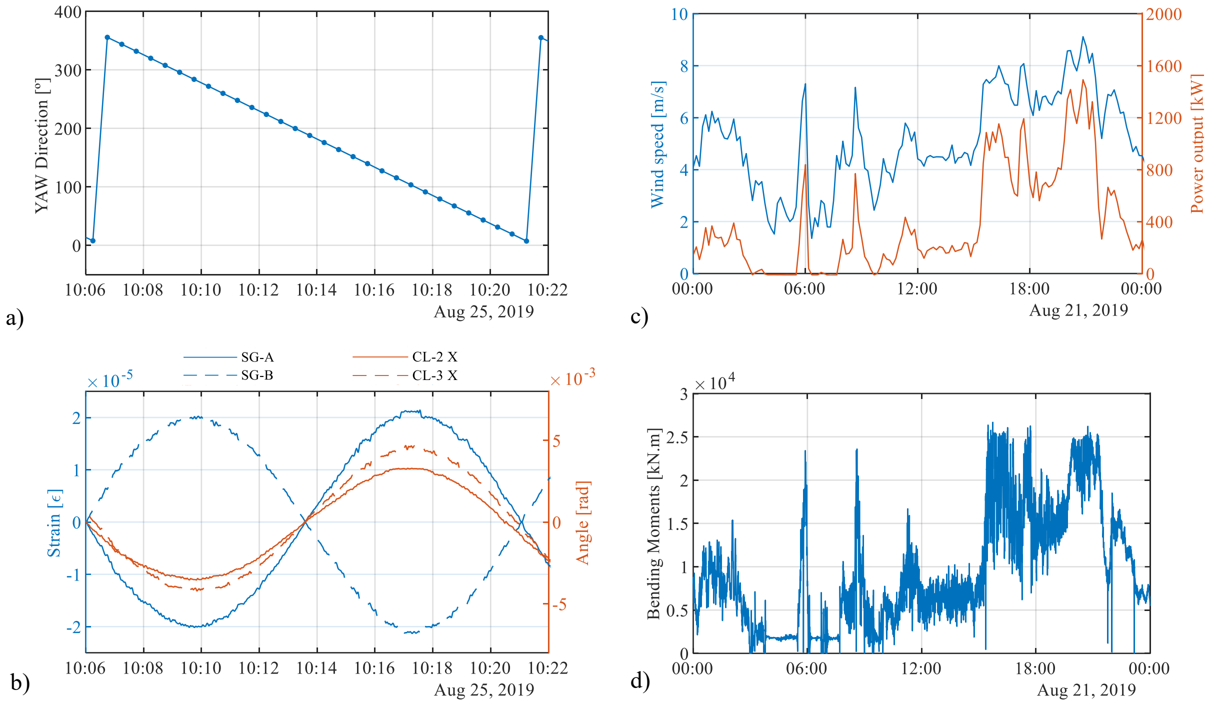

Figure 1 (a) Yaw angle of nacelle; (b) Strain gages and clinometers signals for full rotation of the nacelle; (c) Wind speed and power production during one day; (d) Bending moments at the base of the tower during one day

Special attention is given to tuning of the strain signals processing, which includes temperature effects compensation and signal calibration according to IEC 61400-13 [2]. To eliminate the temperature effects, the thermal output of each raw signal was subtracted using compensation curves provided by the gauge manufacture and the reading of the temperatures. The calibration requires yawing the nacelle 360º below cut-in wind speed, as shown in Figure 1(a). The full rotation of the nacelle generates a sinusoidal signal due to eccentricity of the nacelle and rotor mass. The mean of this signal represent the zero point. Figure 1(b) shows the signals obtained with the strain gages (blue lines) and clinometers (orange lines) in a full rotation of the nacelle. The maximum bending moment obtained with both strains and rotations is similar, but it should be referred that the moments derived from the clinometers are very sensitive to the calibration. Figure 1 shows also the variation of the bending moment during one day (d) estimated from the strains and its dependence with the wind speed and of power output (c).

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[2] International Electrotechnical Commission 2015 *IEC 61400 Wind turbines - Part 13: Measurement of mechanical loads*, Geneva, Switzerland