Uncertainty associated with strain gauge measurements on wind turbines

M.Bezziccheri[1],N.Paone[1,2],P.Castellini[1,2],C.Santolini[1,2],P.S.Evangelisti[1,2]

1) Università Politecnica delle Marche, DIISM, Ancona, Italy
2) WEST-lab, Facoltà di Ingegneria, Università Politecnica delle Marche, Via Brecce Bianche, Ancona, Italy

ABSTRACT

The capacity of a wind turbine to successfully enter the market is strongly linked to its transformation efficiency and compliance with declared specifications. Generally, compliance is guaranteed by certifying the wind turbine according to international standards. Specifically, the internationally accepted standards are those released by the International Electro-techincal Commision (IEC), which has developed a very strict and detailed regulatory package, summarized in IEC-61400. In particular, IEC-61400-13 describes the method and related techniques for the experimental determination of the mechanical loads on wind turbines, focusing primarily on large machines (> 40m^2) with horizontal axis.

The most common method of measuring mechanical loads, recommended by IEC 61400-13, uses a strain gauge sensing system. The main problems associated with the use of these sensors are represented by the complexity of calibration of the measuring system, as well as the influence of the thermal effects on the result of the measurement. In synthesis the evaluation of the uncertainties inherent with the mechanical loads measured is an issue which deserves an in depth analysis.

In this context, the aim of this research paper, is to propose a calibration method supported by a kinematic and dynamic model, figure 1, able to replace traditional methods in cases where direct application of known mechanical loads is impractical, due to size of the turbine or to environmental conditions of the specific installation.

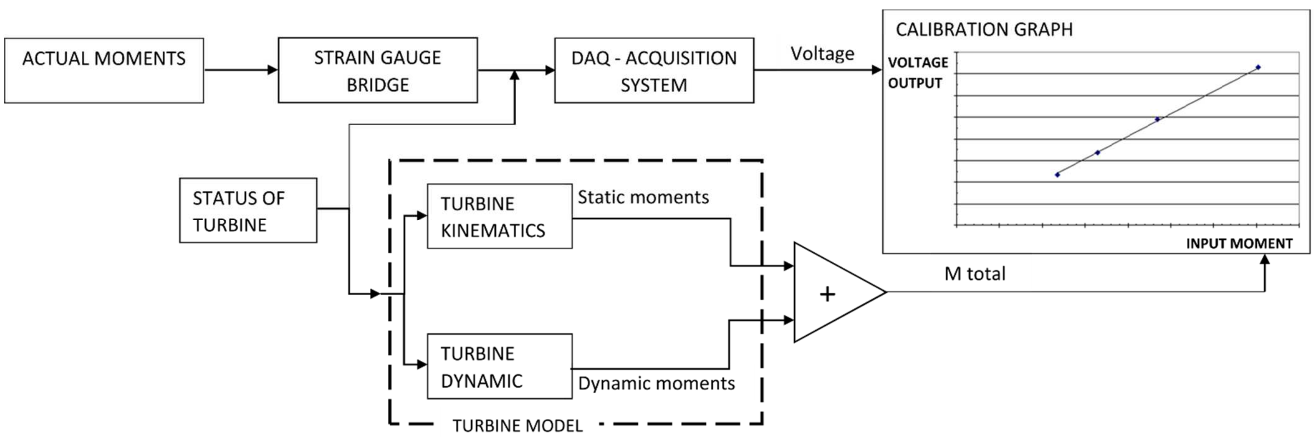

Figure 1 Scheme of calibration

The proposed method is able to describe the mechanical loads on the machine when operating in static and dynamic conditions of for wind speed lower than the cut-in.
The methodology can be useful also for the periodic calibration checks required by the standard. In fact, they may be performed remotely, without application of external loads and avoiding the presence of specialized personnel in the site and the stop of the machine that would be necessary in the case of calibration and in periodic calibration check, as long as the weather conditions are acceptable.
Uncertainty of the method is discussed with reference to the main sources of error inherent in strain gauge measurements, of which thermal effects represent a significant part.
As suggested in the IEC 61400-13, the uncertainty in measurements performed for the identification of mechanical loads on wind turbines must be determined in accordance to ISO Guide to the expression of the uncertainty of measurement. However, since this guide does not provide practical procedures for the situation in question, the IEC 61400-13 proposes to determine this uncertainty via the Monte Carlo method.
The novelty of this research is to propose an approach of type B for uncertainty estimation, as an alternative to the Monte Carlo method, thereby reducing the number of necessary information; the method requires a kinematic/dynamic model of the turbine and of the measurement system.
Concerning thermal effect, despite that current state of the art is based on strain gauges applied in mechanical load measurement, the importance of the thermal effect on the uncertainty is not discussed in existing literature. This article will discuss the possible thermal contributions that could occur on the strain gauge installed on large wind turbines, such as solar radiation, external/internal convection and radiation conduction from generator.
The combination of these effects will determine, in certain situations, a significant imbalance of the strain gauge bridge. The proposed methods, to account for thermal effects will be two:

1. The thermal effect will not be compensated and the entire contribution will enter as a uncertainty in the result;
2. The thermal effect will determining a known offset and the uncertainty on the temperature compensation will affect the overall uncertainty. The thermal uncertainty identified will be function of variance and covariance of temperature measurement.

From the comparison between the two, it will be possible to identify what will be the limit thermal gradient beyond which it will be necessary to use the second method. In fact, at the expense of the installation of a temperature sensor for each strain gauge, the second proposed method will allow to reduce considerably the uncertainty of the problem arising from the thermal contribution.

To allow a better understanding, it is also given a full explanation of the method through the application of the latter to a turbine of 2 MW.