A Condition Monitoring Algorithm for Analysing Tower and Foundation Integrity

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Introduction

The analysis of tower and foundation integrity currently relies heavily on inspections (which may include destructive testing) and/or on the installation of additional sensors, such as strain gauges installed at the tower base. As the collection of SCADA data at high frequency (1 Hz or above) becomes more popular, an attractive alternative becomes available – that of identifying and tracking the main structural frequency of the tower to detect any changes that may indicate tower or foundation failures. Advance knowledge of such failures may be essential to avoid catastrophic failures and also allows owners/operators to schedule any remedial work that may be necessary at periods of low wind, as well as the adoption of suitable de-rating policies to continue operation of the turbines without exacerbating the failure. This paper describes a condition monitoring algorithm which analyses the integrity of a wind turbine's tower and foundation and presents the results of the application of the algorithm to operational data from a real wind farm.

Approach

The proposed condition monitoring algorithm uses high frequency SCADA data (i.e. above 1 Hz) to identify the frequency of the first tower mode and the associated levels of energy, using a combination of frequency analysis, filtering and of a detection algorithm. The resulting values of frequency and energy content can be analysed both in the context of historical trends for the same turbine and of variations between turbines in the same wind farm.

Main Body

High frequency SCADA data from an operational wind farm was collected and analysed by calculating the autospectra of two signals (generator speed and nacelle acceleration) using hourly windows and then processing them with a convolution filter, shaped to increase the relative magnitude of the peaks at structural and aerodynamic frequencies with respect to noise and low frequency variations due to wind. An algorithm which detects a peak in a given frequency band was then applied to the resulting waveforms to identify the 1st tower frequency and measure the energy associated to this structural mode. The structure of the overall algorithm is shown in Figure 1.

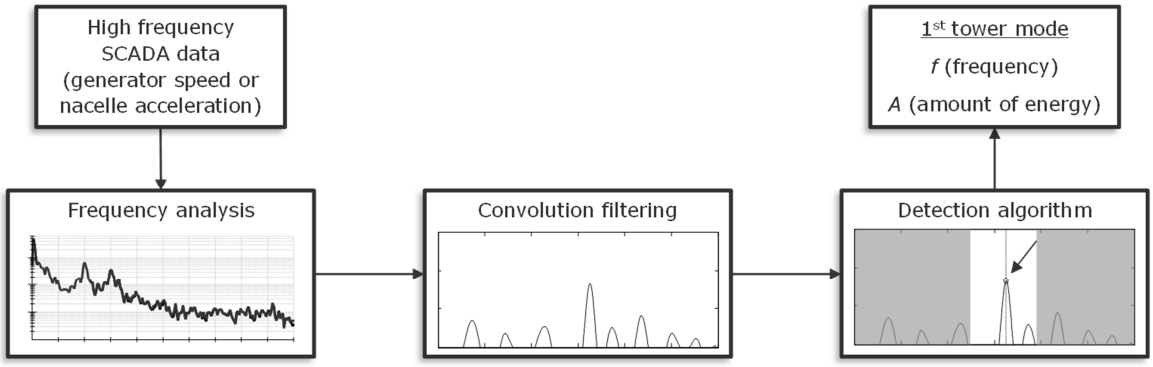

Figure 1: Structure of the condition monitoring algorithm.

The values of frequency and energy content thus determined were analysed both in the context of historical trends for the same turbine and of variations between turbines in the same wind farm, to identify any changes in time or across the site that may indicate reductions in stiffness symptomatic of sudden or gradual tower or foundation failures. The results show that the algorithm is very effective in identifying the characteristics of the 1st tower structural mode and that any changes can be easily detected, both when using the nacelle acceleration signal (which produces clearer results) and the generator speed signal (which is more commonly available within the set of SCADA signals).

Conclusion

The work presented here shows how the availability of high-frequency SCADA data provides the basis for the introduction of condition monitoring algorithms focused at identifying and tracking the frequency and the energy of the 1st tower structural mode. This allows, without resorting to frequent inspections or additional sensors, the early detection of shifts in tower or foundation stiffness which may indicate failures both sudden and gradual, avoiding catastrophic failures and affording an owner/operator the opportunity to schedule any necessary remedial work at periods of low wind and possibly to adopt suitable de-rating policies. Early investigation suggests that the results of this work can easily be extended to identification and tracking of the frequency and energy of the rotor frequency ("1P"), which are good indicators of mass and aerodynamic rotor imbalance.

Learning Objectives

This work describes a new condition monitoring algorithm for analysing the integrity of wind turbine towers and foundations without the need to carry out inspections or install additional sensors. The application of the algorithm to real-world operational data and its results will be discussed, as well as what options advanced knowledge of structural failures affords to owners and operators.

Attendees will learn about the structure of the algorithm and about its potential applications for one-off analysis or ongoing condition monitoring. The presentation will also show the advantages of having access to high-frequency SCADA data and provide examples of other potential condition monitoring applications.