Abstract

Wind farm owners and operators are constantly seeking new ways to improve the performance of their wind turbines, reduce downtime and maintenance costs, increase operational efficiency and extend the life of their assets, thereby reducing levelised cost of energy.

To address these needs, over the course of 2017 we have developed WindGEMINI, an online digital twin which models different aspects of an operating wind turbine. Already popular in other industries, Digital Twins provide an attractive solution which allows OOs to optimise servicing and supply chain strategies inspections.

In this poster we present the WindGEMINI framework and algorithms and explain how OOs can make use of the digital twin outputs to optimise servicing and inspections, and to inform their financial modelling and strategic decision-making processes with a realistic indication of the condition and value of their assets.

WindGEMINI framework

One of the key challenges in using real wind farm data is their acquisition and processing. Any algorithm running on field data needs to be able to cope with duplicate, missing and/or incorrect records.

We have developed a framework based on three elements:

1. A universal acquisition interface, which can read data in from a variety of sources (including e-mail, FTP, OPC) and extract the relevant channels, which are fed into...

2. ...an algorithm layer, which comprises a number of physics-based simulation models which capture different aspects of an operating wind turbine and are continuously updated in near real-time, making use of the stream of information received from the turbines and wind farm sensors. Currently these include i) SCADA-based condition monitoring (SCM) ii) structural integrity algorithms based on high-frequency data iii) a fatigue life estimator

Other algorithms, including a performance watchdog which identifies power curve performance issues, are under development. The results of the analyses are then made available to...

3. ...an interface server, which allows OOs to visualise all the performance and condition metrics via an online portal as soon as they are calculated.

SCADA-based condition monitoring

The SCM algorithm is based on trending of the temperature signals from the wind turbine drivetrain. A period of normal operation is used to establish an expected relationship between a number of input signals (power, ambient temperature, rotor speed) and the drivetrain temperatures being monitored. This relationship is then used on an ongoing basis to generate expected values of the temperatures. When the difference between these expected values and the real ones measured by the turbine sensors exceeds a threshold, alerts are raised automatically to prompt a review of the data and, if necessary, an investigation. In the real-life example shown below, the difference between the expected and actual temperatures measured at the non-drive end generator bearings exceeded alert levels in August 2015, prompting an inspection which resulted in a recommendation to replace the bearing. A pre-emptive replacement in September resulted in only 12 hours of downtime, much less than if it had occurred in response to a fault.

High frequency data analysis

Where high-frequency (>1Hz) data from the turbine sensors are available, a structural integrity algorithm performs frequency domain analysis to identify the frequencies and energy content of the main structural modes and track them over time. Data acquisition rates above 1Hz permit for instance the identification of the 1st tower mode and of the rotor frequency (1P). These can be monitored over time to spot unexpected changes in frequency or energy which may be indicative of foundation issues, rotor mass or aerodynamic imbalance, etc.

Note that this algorithm does not require additional sensors as the main structural modes are visible in standard SCADA signals such as generator speed in the example shown here.

Fatigue lifetime estimator

The fatigue lifetime estimator makes use of 10-minute SCADA signals to estimate the site conditions experienced by the turbines on the field. The effect on the cyclic loading of different structural components is calculated via a loads database generated using a full aerelastic model of the wind turbine. The loads database captures the loading associated with different modes of operation as well as with downtime. Uncertainty is calculated and propagated via sensitivity analysis. This approach allows the algorithm to run with a generic limited data set (and higher levels of uncertainty) or to make use of more complex signals (accelerometers, blade loads, LiDAR) to reduce uncertainty. The resulting estimate of accumulated fatigue is translated into an equivalent “age”. OOs can monitor the aging of their turbines, identify opportunities to extend life or increase power rating, and prioritise inspections using a risk-based approach.

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