Background

Wind turbines are a major part of the renewable energy market. Maintenance and correct operation of wind turbines can increase their reliability by 99.5%; this is a significant factor for the industry, given that in the UK alone, there are approximately 164 incidents per year associated with machinery failure. It has been shown in studies that preventive maintenance costs 25% less than reactive maintenance and predictive maintenance, 47% less. In addition, some 30-40% of maintenance costs are inspection related.

The motivation for the WindTwin project is to provide a solution, targeting the rapidly-growing wind turbine maintenance and operations market, that will help to reduce the maintenance costs of wind turbines and as a result, optimise both operations and energy generation. To achieve this goal, the project integrates and develops enabling technologies, including: condition monitoring sensors and algorithms; high-performance cloud computing; system fault and degradation modelling; data analytics; and visualisation. These techniques are being integrated into a high fidelity, digital platform prototype where sensor and operational data are combined with physics-based models into a digital twin. The virtual model, or digital twin, will combine the mathematical models describing the wind turbine's multi-domain dynamic behaviour, including degradation effects, with sensor data collected and processed from the actual physical asset during real-world operation.

Applications of digital twin models will allow wind turbine operators to: better diagnose performance variations; anticipate degradation and failures, and deploy condition-based maintenance instead of schedule-based strategies. These advancements will reduce downtime, and inspection and maintenance costs, enabling operators to virtually test maintenance upgrades before deployment and to better control wind turbine settings in order to optimise performance and energy output.

WindTwin offers an innovative solution, not only to the wind turbine market but also to other sectors such as marine, robotics and heavy machinery. The digital platform solution is the result of the combined expertise of several companies, working together collaboratively in a consortium, to combine: software development; system and fault modelling; engineering simulation software; high-performance computing (HPC) cloud platforms; condition monitoring; and inspection techniques.

The consortium responsible for developing the WindTwin project comprises Agility3, Brunel University London, Dashboard, ESI and TWI Ltd. The project is co-funded by Innovate UK, the UK's innovation agency. The project started in June 2017 and is currently under development.

Innovation

A sensor network system, utilising optimised signal processing and condition monitoring algorithms, is applied to the live wind turbine to collect operational data which will interface with a replica, virtual 3D model, or digital twin, of the wind turbine. The output is collated and the processed data provides a description of the wind turbine's multi-dimensional, dynamic behaviour and physical state during real-time operations. WindTwin also offers a module in which the design of a degraded system can be created and tested before it goes into production.

By using digital twin models, wind turbine operators will be provided with up-to-the-minute data on how their assets are performing rather than having to schedule regular shutdown times for inspection and investigation, the outcomes of which may result in the unwelcome detection of faults in wind turbines that have developed over time. Furthermore, the combination of condition monitoring with real-time data collection, wireless data transmission, finite elements modelling simulation and visualisation, will allow WindTwin to predict failure of the wind turbine before it occurs.

WindTwin can be differentiated from other systems already on the market due to the depth of capability it offers end users. One advantage is its capacity to optimise the operation of the wind turbine by incorporating a real-time digital twin model with wear and tear, in comparison with other systems that are based on sensor data collection and analytics, without any multi-physics modelling. Another benefit is that WindTwin makes use of condition monitoring and inspection strategies, giving operators the opportunity to remotely control the wind turbine. Lastly, the platform gives users the option to examine a degraded model and test its viability, before it is subject to real production conditions.

Collaboration

From the project outset, the consortium partners have worked together to combine their expertise and identify what is needed, in order to develop the WindTwin platform. Their knowledge in different sectors and complementary technologies have been key to creating the WindTwin platform, which can be characterised by its ability to remotely monitor wind turbines and identify their degradation level.

WindTwin offers a digital platform for designing, maintaining and optimising the operation of wind turbine assets. It improves on current state-of-the-art solutions by developing a software platform for monitoring, optimising and predicting wind turbine performance, thereby reducing operational and maintenance costs. The project partners are combing operational sensor, and virtual system model, data into a single software platform, using enhanced intelligent algorithms, for the purpose of predictive maintenance of wind turbines.

Operational sensor data will be collected from the live wind turbine and, through optimised signal processing and data interfacing, combined into a virtual model in a joint effort between Brunel University, Dashboard and TWI Ltd. A sensor network system, developed by Dashboard and TWI Ltd, will be deployed to the main components of the wind turbine and Brunel University is developing condition monitoring algorithms to assess the state of the wind turbine based on the operational and sensor data. A virtual model and visualisation platform are being built by Agility3 and ESI to communicate the current condition of the wind turbine to the operator.

ESI system modelling tools are being used to develop nominal and fault models for the wind turbine that will introduce the effect of degradation and ageing in the physical system components and sub-systems. These models are simulated in a virtual environment incorporating different operational scenarios, variation in wind loads and environmental effects. Conditioned sensor and operational data will be fed into these digital models, and intelligent algorithms will be developed to update a hybrid digital twin by comparing simulation data with real-time sensor data.

Collaboration is very much at the heart of the WindTwin project, as demonstrated by the success in securing co-funding from Innovate UK for the venture. Since the project's inception, close working and regular communication have enabled the consortium partners to achieve the desired outcomes as the project progresses. Conference calls and face-to-face meeting are used to both brainstorm ideas as well as overcome any difficulties which arise as a result of the complex technologies involved. The unique expertise and experience each partner brings to the project is highly valued by the members of the WindTwin consortium, who take an inclusive and team-based approach to managing the project. As well as the technical development of the digital twin platform, the partners are also involved in publicising interim results to the industry at key stages of the project and are developing a business plan and go-to-market strategy for the future.

Impact

The WindTwin project combines partners' technologies into a common platform for creating an accurate, hybrid digital twin of a real wind turbine asset. The WindTwin solution will be used by wind turbine owners, operators, and independent service providers to aid in the maintenance and operation of wind turbines.

When it is fully realised, WindTwin will be well positioned to exploit the opportunity offered by the continued growth in wind power generation in the UK. At the beginning of November 2016, the UK had 6,999 wind turbines in operation with a total installed capacity of over 14.1 gigawatts. WindTwin will give wind farm operators and owners more control over their assets as they will be able to control their wind turbines themselves and rely less on the services offered by manufacturers. End users of WindTwin will feel more confident in the performance of their wind turbine assets as they will be able to monitor and use the digital platform remotely, and it will provide them with all the information they need on each wind turbine to asses its current state of health and degree of ageing.

In addition, there is a wider impact correlated with the use of the WindTwin platform, namely a reduction in inspection costs; often high as inspection processes are manual and the associated equipment is expensive, by 30%. When the percentage is calculated, this brings the potential savings up to £18 million per wind turbine, on average, for an offshore wind farm.

In terms of environmental impact, the WindTwin platform is a reliable tool for condition monitoring and inspection of wind turbines, attractive for end users and producers as it will make wind turbines more efficient with less downtime so they can keep generating power, which benefits the wider environment and green efforts that using wind energy brings.

Summary

WindTwin will provide solutions and benefits to the wind turbines industry by enhancing the quality of operation; providing real-time data describing the performance of the asset; reducing significantly operation and maintenance costs; improving environmental footprint for wind turbines.

The combined knowledge of the consortium partners, together with their experience in different sectors, has been key to create the digital twin platform. WindTwin will give wind farm operators and

owners confidence for the future. They will monitor and use the digital platform remotely, providing them with all the relevant information about the current state of health of their wind turbines.