Project Title: Veers' Extension to Non-neutral Incoming Winds (VENTI)

Project type: Flexible funding 1st Call 2019

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Project Summary

As our society becomes ever-more dependent on wind power, it is increasingly important to gain a deeper understanding and more accurate predictability of the wind power availability, the aero-elastic fatigue loads on the wind turbine blades/drive train, and the associated issues of turbine control. The Sandia method proposes to numerically simulate the instantaneous three-dimensional wind field impacting on a wind turbine based solely on information from the frequency spectrum of the incoming wind (i.e., PSD) and its two-point velocity correlations in space across the turbine diameter. This method of prediction is particularly appealing for industrial applications due to its fast turnaround time and its proven agreement with field measurements. This project investigated the applicability to the Sandia method to different non-neutral atmospheric states that often occur in real applications. The project shed light on changes in velocity correlations (and turbulent lengthscales) due to the combined affect of atmospheric stability and the presence of the wind turbines.

Progress (Mar 2021 – Sep 2021)

The last few months of the project have been dedicated mainly to two activities: (i) expanding the test matrix by carrying out additional experimental work (including different atmospheric states and number of wind turbines to complement existing data); and (ii) preparation of the project findings for dissemination both via international conference attendance and peer-reviewed journal publication. An overview of some of the available experimental data is included in the slide pack, together with a record of the dissemination activities. The overall project impact is also captured in the slide pack, which also details the project findings to date.

Progress (Sep 2020 – Mar 2021)

After the EnFlo Lab reopening following the first Covid-19 lockdown, the activities within the project have resumed. Due to a combination of a lack of technical personnel and a hiring freeze policy within the department, some activities (electronics work) had to be outsourced. In preparation for further wind tunnel tests, we have developed a new integrated fully-digital wind turbine controller that supersedes the previous one in performance allowing a much higher degree of monitoring of the turbines in operation, whilst also increasing the number of wind turbines that can be accurately operated simultaneously. This new controller (see figure 1) can be embedded in the base structure of the turbines and allows for in-situ estimation of the rotor friction, hence guaranteeing much more accurate and tailored monitoring of the aerodynamic torque on the turbines, which is affected by the incoming wind turbulence. To the best of the authors' knowledge, this is the first of this kind.

Figure 1: New digital wind turbine controller. (left) CAD model, (centre) prototype board with scale, and (right) final delivered product.

Preparation for dissemination of the findings in an international peer-reviewed journal is currently underway, with the first draft manuscript nearly ready.

Further activities carried out to date:

- Purchase of two new drivetrain assemblies (generator/gearbox/encoder) to replace damaged equipment;
- Maintenance of blade pitch alignment rig;
- Alignment of blade pitch for all necessary wind turbine models;
- Detailed design of further experimental work;
- Detailed wind tunnel data analysis for dissemination purposes.

Progress (Jan 2020 – Sep 2020)

Experimental test design and preliminary wind tunnel work were carried out between January and March 2020, i.e., before the laboratory closure due to COVID-19. The project has been effectively on hold since then, due to a combination of a lack of technical personnel (furlough scheme) and laboratory closure. The latter has recently reopened, with a backlog of research activities slowly restarting. The only activity possible during the Lab closure has been the analysis of the preliminary wind tunnel data to inform future activities and its preparation for dissemination (currently underway).

Further activities carried out to date:

- Maintenance of two wind turbine models including drivetrain assembly (generator/gearbox/bearing), controller, and blade pitch alignment;
- Maintenance of blade pitch alignment rig;
- Measurements of two-point velocity correlations in neutral, and moderately stable (with and without an overlying inversion) boundary layers in different scenarios: (i) in the absence of wind turbines, (ii) in the presence of 1 wind turbine, (iii) in the presence of 2 wind turbines;
- Preliminary wind-tunnel data analysis;
- Design of future experimental work.