

WAKE DEVELOPMENT AND INTERACTIONS WITHIN AN ARRAY OF LARGE WIND TURBINES

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INTRODUCTION

The investigation of wake development and wake interactions within an array of wind turbines is a key objective in the EnFlo windtunnel laboratory contribution to the EPSRC funded **SUPERGEN V - WIND ENERGY TECHNOLOGIES** project. The overall project challenges are to improve the efficiency, reliability and operation of large wind turbines, to develop new design concepts for large wind turbines and to optimise the siting of large wind turbines. The Research activities are carried out by Universities and actively supported by 10 Industrial Partners (for more detail on the project see <http://www.supergen-wind.org.uk>)

The wind flow characteristics and the influence of upstream turbine wakes are strong factors in determining the density with which the turbines can be placed within a wind farm and the energy yield per unit area. Extracting energy from the wind, the turbine wake is generally characterised by reduced wind speeds and increased levels of turbulence. Within a wind farm array, where the effects of several wakes interact, turbines therefore produce less energy and can be subjected to greater loads than single turbines placed in the free stream (see e.g. Burton et al. (2002); Vermeer et al. (2003)).

The decrease of momentum deficit in the wake of a wind turbine is determined by two primary mechanisms: mechanical turbulence generated by the turbine itself, which is controlled by the turbine design and performance and usually is of a relatively high frequency and small scale, and the turbulence level in the ambient atmospheric boundary layer flow. With the latter being controlled by terrain roughness, topography, stratification, etc., the characteristic length scales as well as spectral characteristics of these two interacting mechanisms are quite different. Moreover, the quantitative effect of the interactions change as rotor size increases.

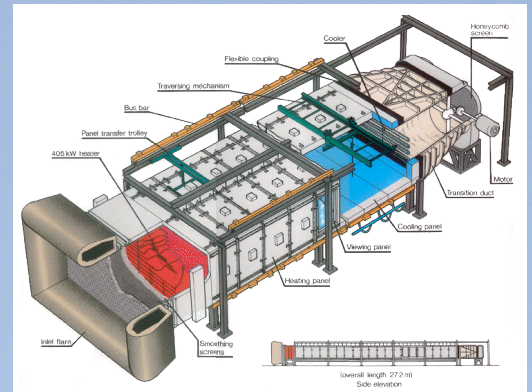


Figure1: EnFlo atmospheric boundary layer windtunnel.

EXPERIMENTAL SET-UP AND PLANNED WORK

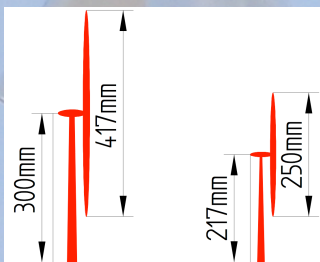


Figure2: Dimensions of the scaled 5MW (left) and 2MW (right) wind turbine models.

Wake characteristics, development and interactions will be studied in the large EnFlo boundary layer windtunnel shown in Figure 1 (working section: $L \times W \times H = 22 \times 3.5 \times 1.5$ m) for two different machine sizes: 5MW with a rotor diameter of 126m and a hub height of 90m and 2MW with a rotor diameter of 75m and a hub height of 65m. A model scale of 1:300 is chosen to ensure sufficient spatial resolution for the wake measurements. Figure 2 gives an idea of the model dimensions for the two machines. Rotating scale model, speed controlled wind turbines will be built, as will simpler gauze-rod representations. Allowing for reasonable longitudinal spacing of 6-8 rotor diameters, up to four 5MW machines (six 2MW machines respectively) will be arranged successively in the test section as shown in Figure 3. Wake interactions of two parallel turbines will be studied using the smaller model turbine (lateral spacing: 3-4 rotor diameters).

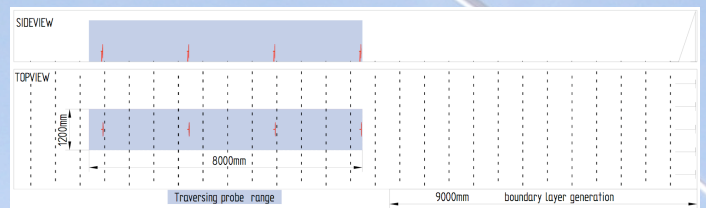


Figure3: Set-up for the 5MW turbine array with a successive spacing of six rotor diameters. Flow from right to left, shaded area indicates the probe traversing range.

The EnFlo windtunnel is de-signed to simulate the atmospheric boundary layer (ABL) under a variety of conditions of surface roughness, terrain and stratification. The planned case studies comprise off-shore ABLs for neutral and stable conditions. In due course, examples of terrain changes (from flat to steep) will be investigated. The wake measurements will be made using Laser-Doppler-Anemometry, including phase-locked measurements to separate ordered motion from genuine turbulence.

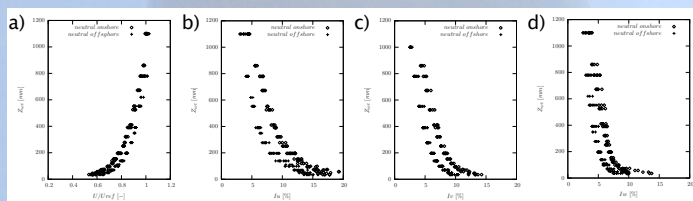


Figure4: Profiles of mean velocity (a) and turbulence intensities (b-d) in the on-shore and off-shore model boundary layers. Profiles were taken at several locations in the probe traversing area range.

REFERENCES

Burton, T., D. Sharpe, N. Jenkins and E. Bossanyi, 2002: *Wind Energy Handbook*. John Wiley & Sons, Ltd.
 Vermeer, L., J. Soorensen and A. Crespo, 2003: Wind turbine wake aerodynamics. *Progress in Aerospace Sciences*, 39, 467-5110.

WORK PROGRESS

Up to now, initial windtunnel experiments were conducted to generate neutrally stratified on-shore and off-shore model boundary layers with characteristic mean and turbulent properties at the appropriate scale. Figure 4 shows profiles of mean velocity and turbulence intensities in the two model boundary layers. Table 1 summarises the boundary layer parameters.

ABL	α	z_0 [m]	u^*/U_0
on-shore (rural)	0.14	0.1	0.05
off-shore	0.1	0.02	0.04