Wind Farm Arrangement: Considering the Influence of Complex Terrain and Turbine Wake Interactions

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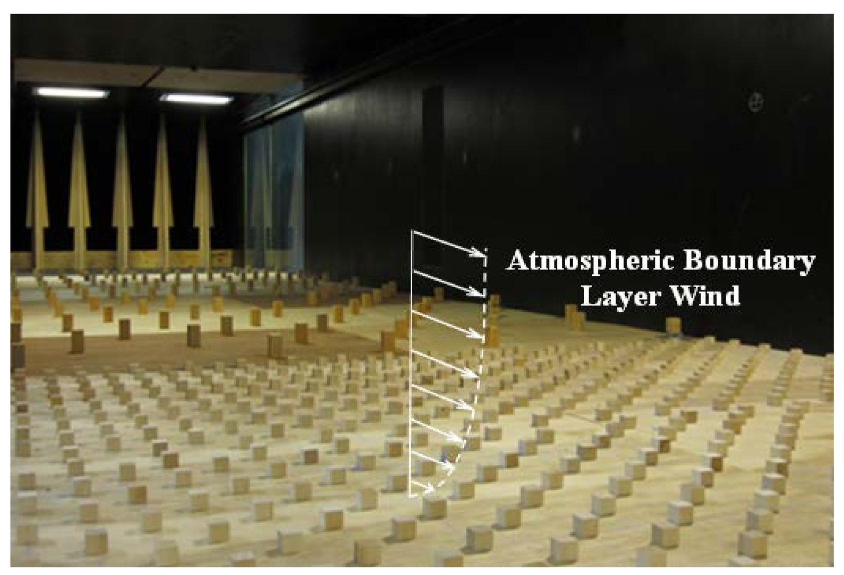
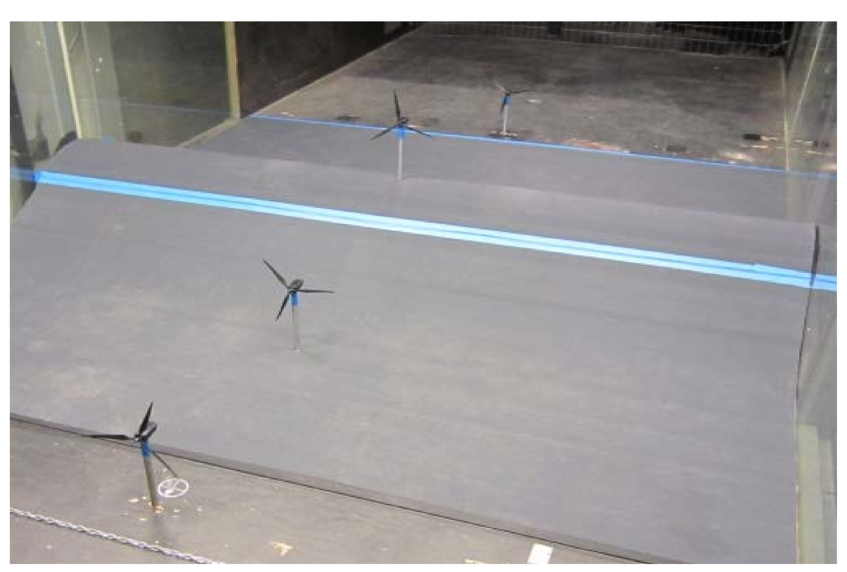
Introduction

Hilly areas might prove appealing wind farm sites due to the speed-up effect of wind passing over a hill. There is, however, an associated decrease in wind speed before and after the hill. [1] Experiments were carried out on model wind turbines sited on a two-dimensional ridge in a wind tunnel to determine the optimal location of a wind turbine on complex terrain with varying ambient turbulence levels, and to investigate the output and fatigue-causing turbulence of individual and multiple turbines in varying positions on the hills with and without wake interactions.





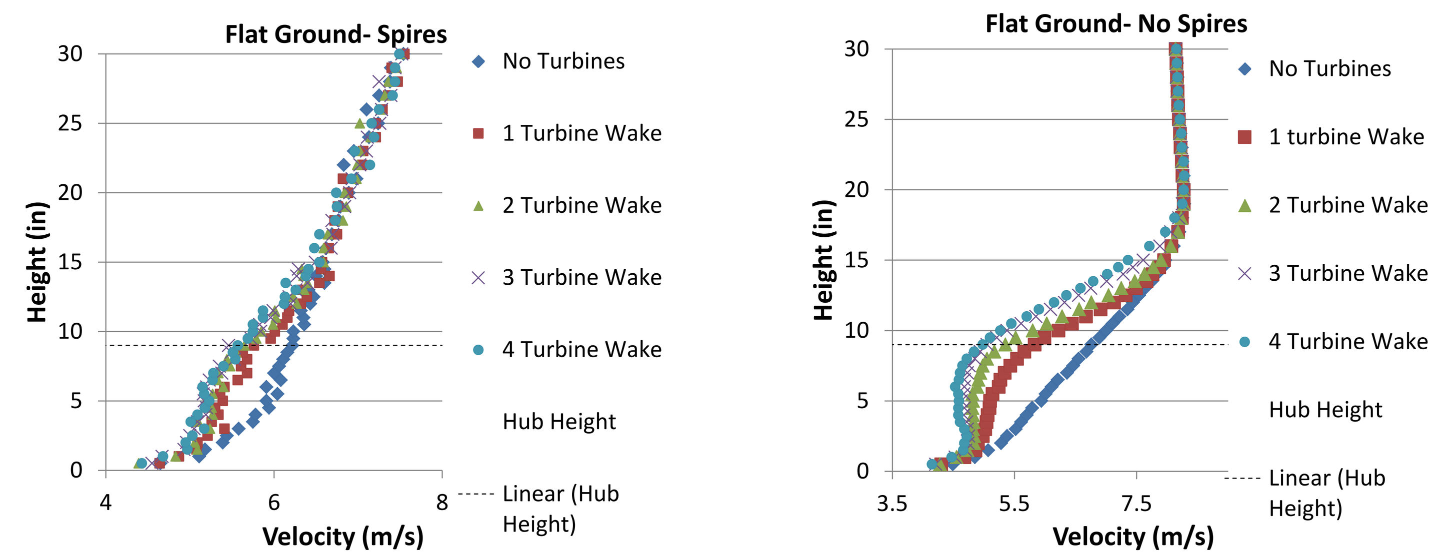
In this study:

- The characteristics of the surface winds were measured, (particularly turbulence, the primary fatigue inducing parameter[2], and velocity, both in the streamwise direction)
- The force and moments, and power output of the turbine models were measured.
- The performance and flow characteristics on the hill were compared with those of a model on flat ground.
- The effects of high and low turbulence (spires vs. no spires) in the incoming atmospheric boundary layer on the performance of the individual wind turbines was observed.

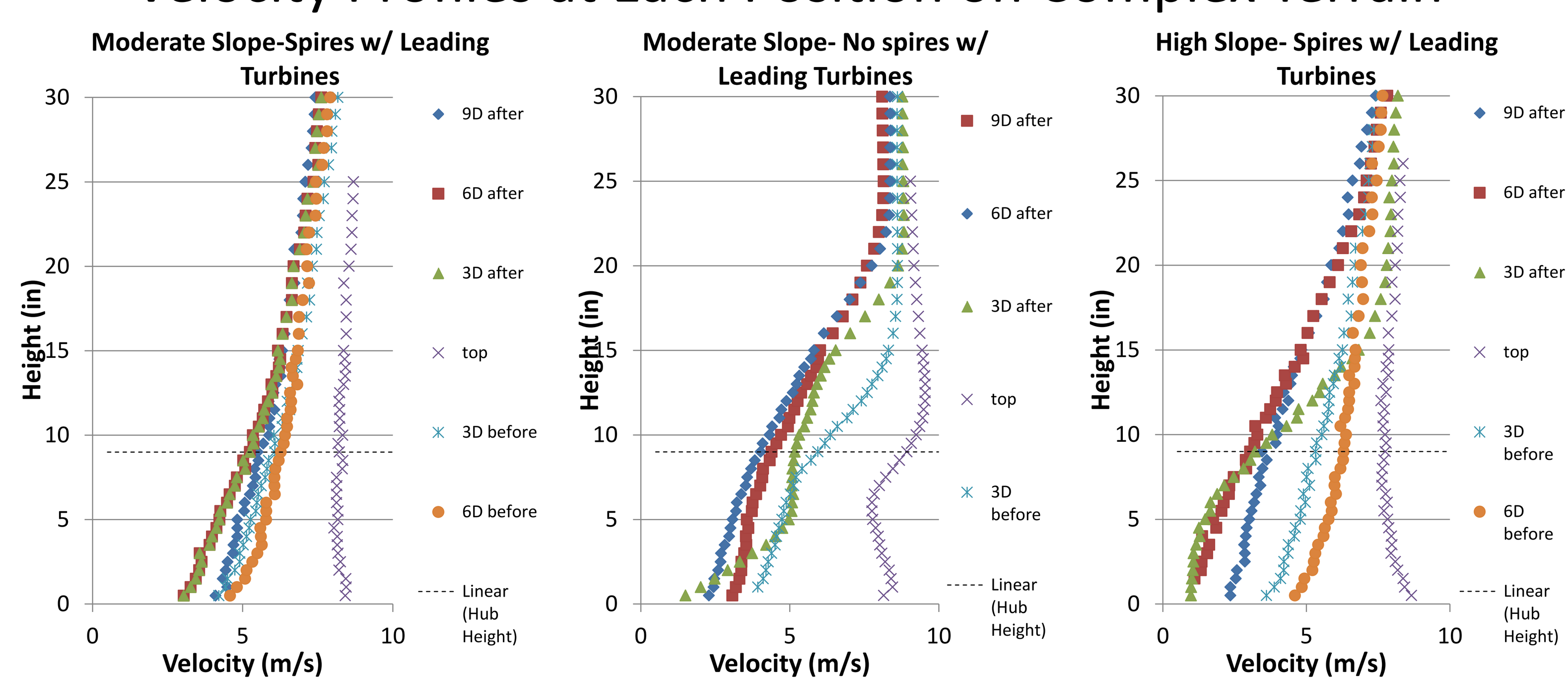
All experiments were conducted in the Aerodynamic/Atmospheric Boundary Layer (AABL) Wind Tunnel in the Aerospace Engineering Department at Iowa State University.

Results

Velocity Profiles at Each Position on Flat Ground

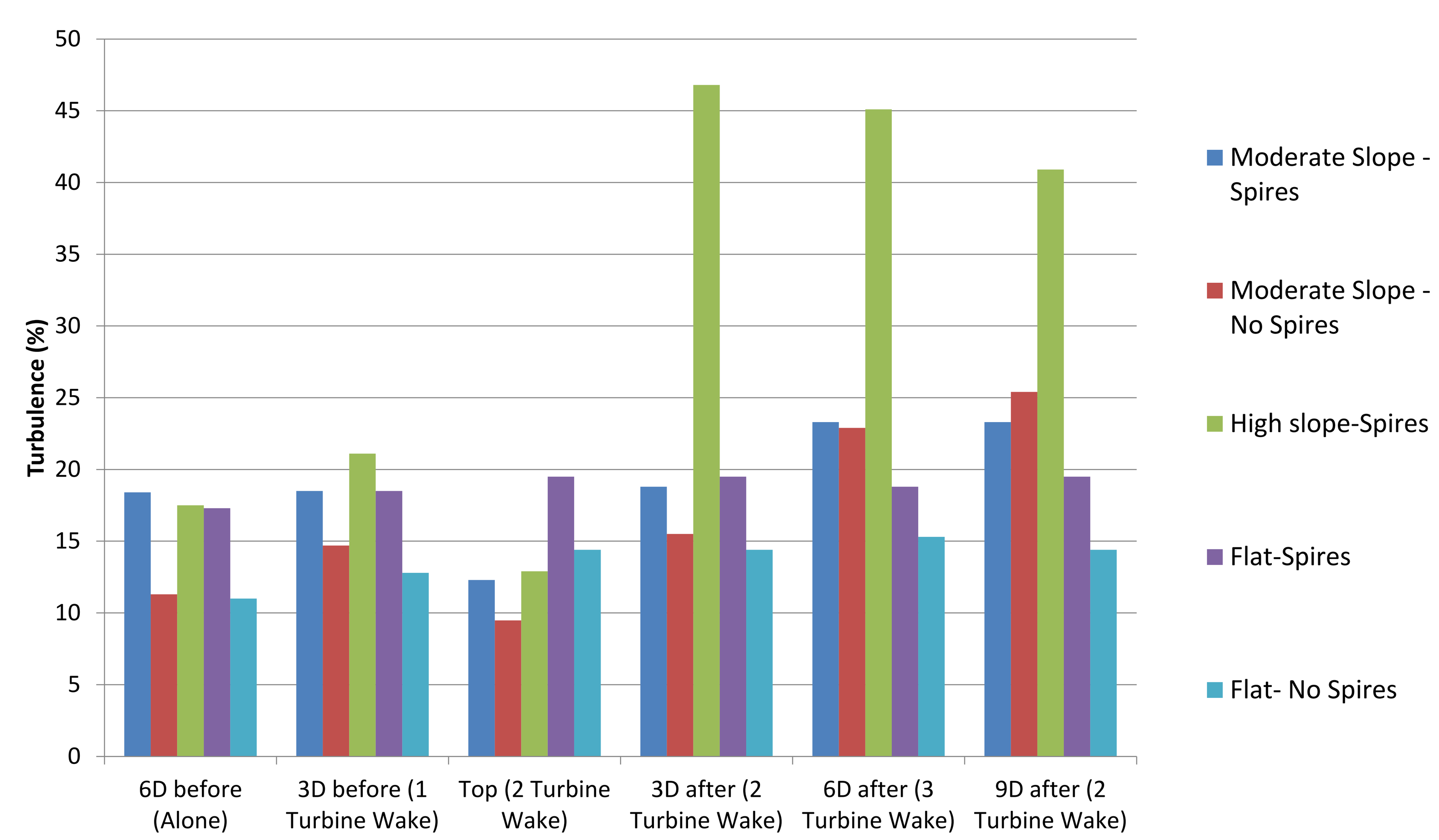


Velocity Profiles at Each Position on Complex Terrain



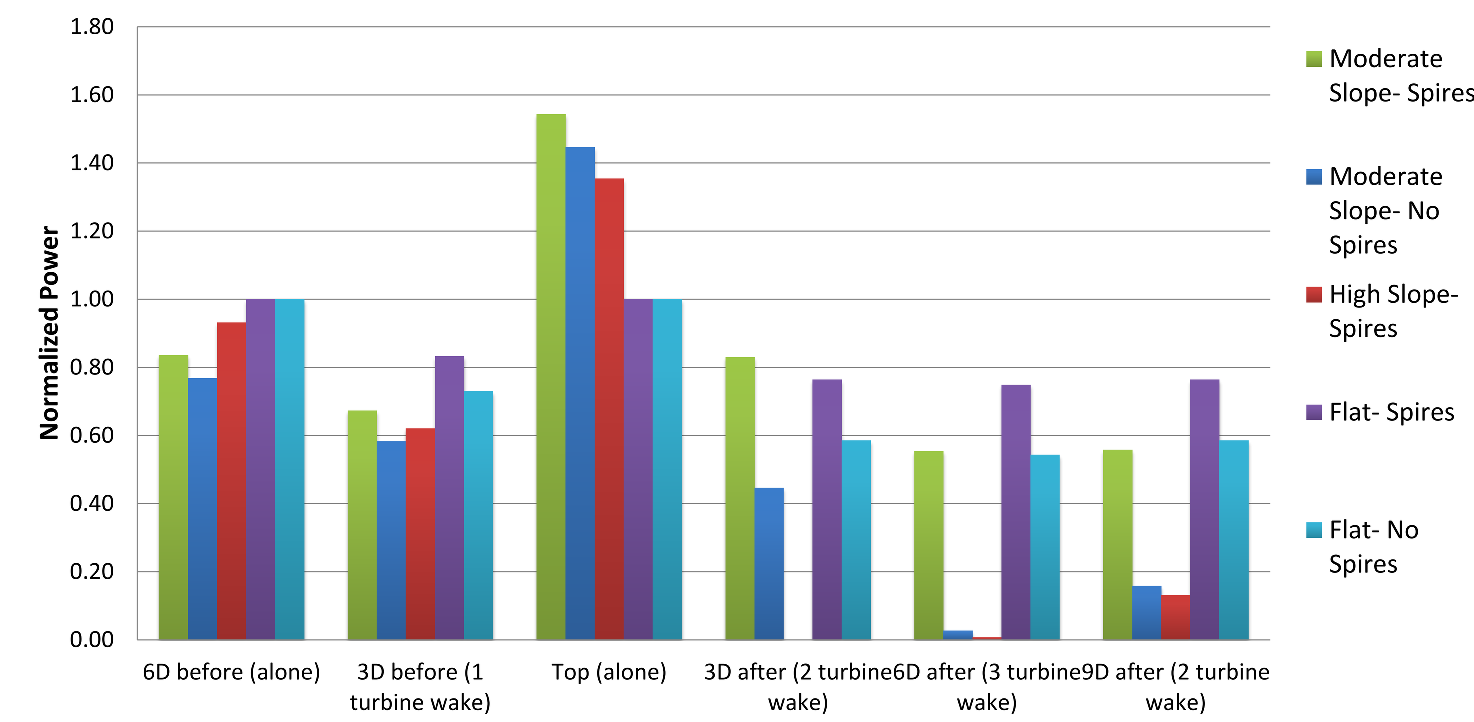
- Large difference between velocity on top of hill in all cases, smaller change in the high slope hill
- Velocity deficit is more pronounced in the no spire/lower turbulence case
- Largest wind shear is largest on the moderate hill without spires

Turbulence at Hub Height



- Turbulence levels are lowest at the top of the hill, and increase after it. This is more pronounced in the high slope case.

Normalized Power of Turbines with Leading Turbines on Complex Terrain



- Each output has been normalized with the output for a lone turbine in the same turbulence level (spires or no spires)
- The high slope output is virtually nonexistent after the hill due to separation of flow on lee side of high slope hill
- The output of the first turbines in front of a hill are slightly less than those placed on flat ground
- The output on top of moderate slope hill is the greatest, though output is greater than a turbine on flat ground for all cases

Conclusions

Wind turbine performance is affected significantly by the terrain of the wind farm. Wind turbines sited on top of the 2D-Ridge in all cases experience higher wind speeds and thus power output, and are exposed to reduced turbulence levels compared to those sited on flat terrain. Turbines sited after a hill however, will experience lower wind speeds and power outputs, and are exposed to higher turbulence levels. The turbine on the top of the moderately sloped hill in the high ambient turbulence case showed the greatest relative increase in output, as well as experiencing low turbulence and minimal wind shear.

Acknowledgements :

Support for this research was provided by a National Science Foundation Research Experience for Undergraduates site program in Wind Energy Science Engineering and Policy (WESEP) at Iowa State University.

References :

[1]Ozbay, A., 2012, "Experimental investigations on the wake interferences of multiple wind turbines," Master's Thesis, Iowa State University, Ames IA.

[2]F Mouzakis, E Morfiadakis, P Dellaportas, Fatigue loading parameter identification of a wind turbine operating in complex terrain, Journal of Wind Engineering and Industrial Aerodynamics, Volume 82, Issues 1–3, August 1999, Pages 69-88.