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Optimisation of Wind Farm Energy Production by Selected Turbine Control

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Wind farms aim to optimally convert the available wind power to electricity, with all turbines facing directly into the wind. However, interactions between the blades and the wind flow reduces the wind speed to downstream turbines and hence reduces their energy production. This process is known as the wake effect. Using optimisation techniques, we can control the power of upstream turbines to reduce the wake effects and increase the generated power across the whole wind farm.

Background

A wind farm produces electricity by converting wind energy into mechanical energy at each turbine. The wind creates a force on the blades of a wind turbine, and so causes the rotor to generate electricity. The turbines in the direct path of the free wind tend to absorb most of the wind energy, producing a wake effect that reduces the remaining wind for the downstream turbines to generate power. A typical wind farm, showing simulated wake effects on downstream turbines is shown in Figure 1 [1]. By controlling the blade pitch angle and the rotor speed of the upstream turbines, the wake effects can be minimised to increase the available wind energy for downstream turbines.

AGL maintains a 140-turbine wind farm in Victoria and seeks to control the power of turbines to either i) maximise power output for the whole farm, or ii) achieve a target power output as set by the market regulator in a dynamic setting.

Research Questions

- How does the magnitude of the wake effect depend on turbine configuration parameters?
- Can we accurately predict power output at each turbine given the graph structure determined by the wind profile at any point in time?
- Can we optimise the decision variable to maximize power output of the wind farm?
- Can we optimise the power output given a dynamically changing wind profile, with minimal delays considering time required to reconfigure turbine parameters, with minimal wear and tear to turbine machinery?

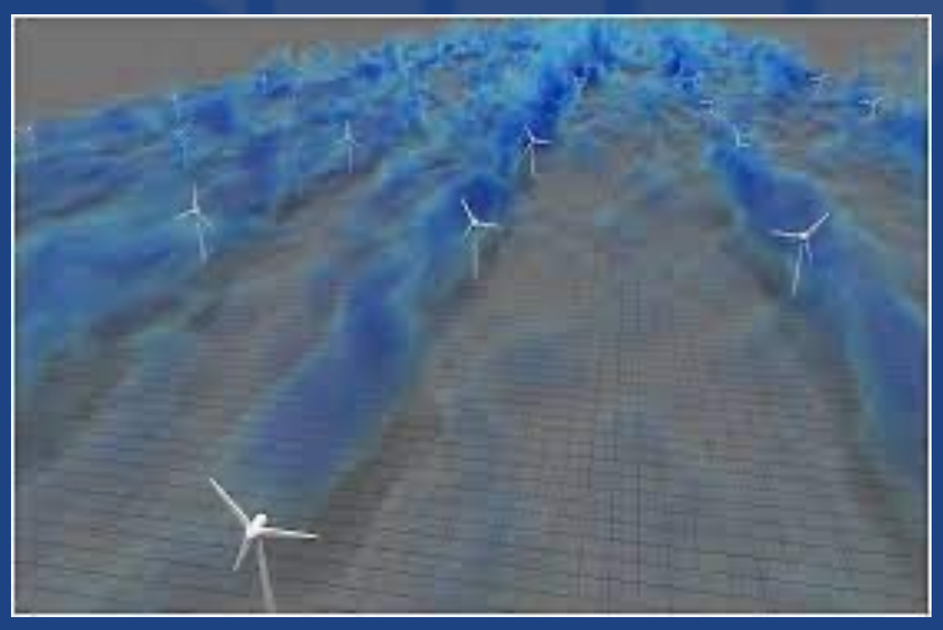

Figure 1 - Wake effects shown across a wind farm, from [1] with visualisarion courtesy of David Bock (National Center for Supercomputing and XSEDE, Extreme Science and Engineering Discovery Environment)

Approach

A graph-based approach can be constructed to model the wind farm with:

- Nodes representing turbines
- Edges between nodes representing downstream relationships
- Weights on edges representing the wind reduction due to wake effects

When the wind changes direction, a new graph structure dynamically emerges and wake effect calculations must be updated.

The challenge is to determine the optimal turbine configuration parameters and target power output for each turbine to meet market energy requirements.

A Bayesian optimisation approach has been proposed, combining a physics-based model of wake effects with machine learning predictions of power output, to control wind energy production under dynamic wind conditions.

FOR FURTHER INFORMATION

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REFERENCES

[1] **Stevens, R. J. A. M., Gayme, D. F., and Meneveau, C. (2016) Effects of turbine spacing on the power output of extended wind-farms. *Wind Energy*, 19: 359– 370.**

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