Experimental design for unsteady aerodynamic wind turbine research in a towing tank

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Wind is a sustainable and abundant resource. In 2023, the wind industry saw its largest annual power increase ever, of 117 GW [1]. Although a large accomplishment, to meet COP28 climate goals the annual installation rate must triple by 2030 [1]. While steady aerodynamics of wind turbines have been investigated widely, work remains when considering unsteady aerodynamics [2], which, for example, can be caused by atmospheric turbulence, terrain variation, or tidal currents – the latter of particular importance for offshore installations. This study aims to support this knowledge gap through experimental testing in a towing tank at Queen's University. The towing tank is 13.6 m long, has a 1 x 1 m cross section, and can achieve a maximum towing speed of 1.3 m/s, and thus a maximum diameter-based Reynolds number of 450,000, while keeping blockage under 10%. A scaled down MoWiTo model turbine [3], widely used in wind turbine aerodynamic experiments, will be used to examine wake development and blade loading under both steady and unsteady conditions; the former allowing comparisons to published results in well-established steady conditions. The MoWiTo typically features a 0.58 m diameter rotor with SD7003 blade profiles [3], which will be scaled down to 0.35 m to meet a 10% blockage constraint. The MoWiTo rotor is designed for testing at higher Reynolds numbers than those achievable in the towing, thus a redesign will be performed using blade element momentum theory to optimize for operating conditions in the towing tank. The planned experiments will run at tip speed ratios between 4 and 8 to match operational in-field conditions. Initial experiments will measure the generated turbine thrust and power in canonical steady conditions and then move to examining effects of unsteady conditions such as gusts or continuously yawing the turbine while in movement.

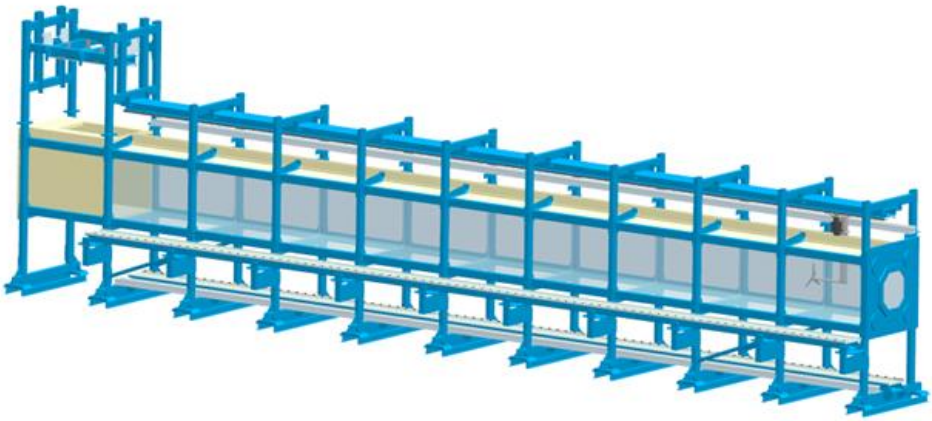

Figure 1:*13.6 m long towing tank located at Queen's University. Note the model mounting platform (far left) and sample model inside tank (far right).*

References:

[1] GWEC, "Global Wind Report 2024," PDF.
[2] R. He, H. Sun, X. Gao, and H. Yang, "Wind tunnel tests for wind turbines: A state-of-the-art review," *Renew. Sustain. Energy Rev.*, vol. 166, p. 112675, Sep. 2022, doi: 10.1016/j.rser.2022.112675.
[3] J. Schottler, A. Hölling, J. Peinke, and M. Hölling, "Design and implementation of a controllable model wind turbine for experimental studies," *J. Phys. Conf. Ser.*, vol. 753, no. 7, p. 072030, Sep. 2016, doi: 10.1088/1742-6596/753/7/072030.

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