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Effectiveness of the actuator line method in capturing unsteady gust interactions with tidal rotors

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ABSTRACT

Tidal turbines operate in unsteady flow environments that prompt complex flow interactions and challenge the validity of existing computational modelling methods. In this study, four numerical models of varying fidelity will be used to simulate a horizontal-axis tidal turbine under small-amplitude axial flow oscillations across a range of frequencies. The objective of the study is to assess the effectiveness of the different numerical models in capturing unsteady flow effects, as well as gaining insights regarding the strengths and shortcomings of each method.

Smyth *et al.* (2024) tested three numerical models for their ability to capture unsteady loads of a tidal turbine: the 2D analytical Theodorsen function, a 3D vortex lattice method and a full 3D viscous URANS blade resolved simulation. While the two 3D models behaved similarly, the 2D Theodorsen function failed to accurately capture the unsteady flow behavior at low gust frequencies (Figure 1), further highlighting the importance of the 3D wake in unsteady load prediction.

In this work, we will incorporate the actuator line model (ALM) to the comparison described above. The ALM is capable of generating a vortical wake, which Smyth *et al.* (2021) demonstrated are critical for the prediction of the loading response of horizontal axis turbines in uniform gusts, however, user defined parameters such as two-dimensional aerofoil data, the flow sampling method and the smearing radius ε, may affect the intensity of the turbine wake and its subsequent effect on the unsteady loads (Zormpa *et al.* (2024), Meyer-Forsting *et al.* (2019)). This study will explore the impact of those parameters and evaluate the ability of the ALM to capture unsteady flow effects at a range of gust frequencies. Comparing the ALM steady and unsteady loads with those from VLM and URANS simulations will provide valuable insights into the ALM's capabilities.

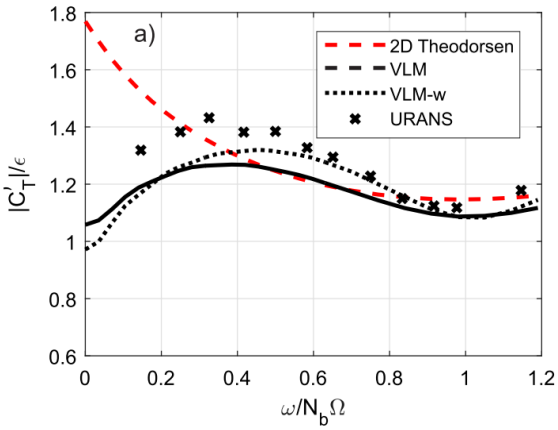

Figure 1: Reprinted from Smyth *et al.* (2024), with permission. Amplitude of the unsteady thrust coefficient from the 2D Theodorsen function, VLM, and URANS. Unsteady load predictions from a fourth model, the ALM, will be included in the comparison under the current study.

References

Smyth, A. M., Young, A. M., di Mare L. (2021) Effect of Three-Dimensional Geometry on Harmonic Gust–Airfoil Interaction. AIAA Journal 59(2), 737. https://doi.org/10.2514/1.J059661

Smyth, A.M., Zilic de Arcos, F. & Young, A. M. (2024) Unsteady gust interaction with tidal rotors: Importance of 3D wake effects and implications for turbine load modelling. Preprint. 2024. https://doi.org/10.21203/rs.3.rs-3688286/v1

Zormpa, M., Zilic de Arcos, F., Chen, X., Vogel, C. R., & Willden, R. H. J. (2024) The effect of flow sampling on the robustness of the actuator line method. Wind Energy. Accepted, In production. https://doi.org/10.1002/we.2965

Meyer Forsting, A. R., Pirrung, G. R., & Ramos-García, N. (2019). A vortex-based tip/smearing correction for the actuator line. Wind Energy Science, 4 (2), 369–383. https://doi.org/10.5194/wes-4-369-2019