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Development of Efficient Numerical Models for Digital Twins and Active Control of Floating Wind Turbines

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ABSTRACT

Fixed and floating offshore wind turbines are increasingly gaining attention due to the high wind speeds available offshore, which are unobstructed by land features (U.S Department of Energy, 2023). In some areas, such as the U.S. West Coast, the coastline drops off rapidly into deep waters exceeding 60 meters, which is particularly suitable for floating wind technology. To improve the lifetime and performance of floating wind turbines, it is necessary to control the platform motions in response to ocean wave and wind loads. The development of efficient numerical models that can run in real time is a critical component of an active control system. Digital twins estimate the performance and motions of the physical counterpart by continuously integrating data from the real-world system. This real-time data exchange enables digital twins to estimate critical, otherwise elusive states for offshore wind turbines, such as tower base moments and mooring line tensions.

This study examines the effectiveness of Deep Operator Networks (DeepONet), Initial Condition Deep Operator Networks (IC-DeepONet), and Long Short-Term Memory (LSTM) models as digital twins for the prediction of extreme wave events for floating offshore wind turbines. The VolturnUS-S floating platform geometry (Allen et al., 2020) is used and the extreme sea-state examined is for a 50-year return period storm with a significant wave height of 9.6 m and a peak period of 16.2 s. The models are trained with data OpenFAST (Jonkman et al., 2018) simulations. This work investigates the capabilities of digital twins to accurately predict the platform motions and mooring line tension. Fig. 1 illustrates a sample time history of wave elevation on the left and surge motion predictions of the digital twins relative to the OpenFAST calculation for an extreme wave that was not used to train the models. This work demonstrates that IC-DeepONet and LSTM approaches consistently outperform the DeepONet across key metrics and that these methods are capable for use as a digital twin in the real-time monitoring and control of offshore turbines.

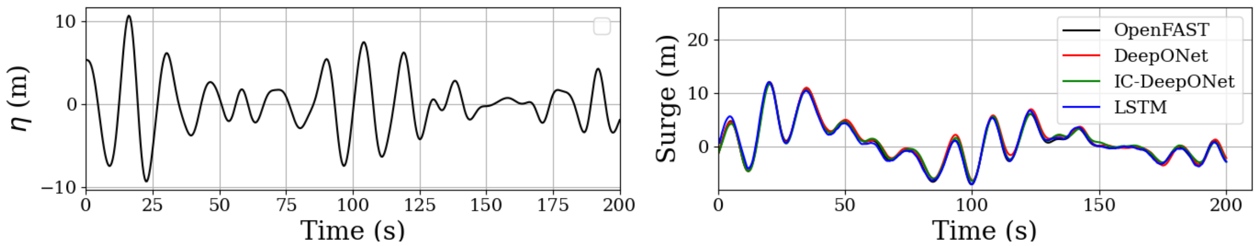

Figure 1: Surge motion predictions of the digital twins relative to OpenFAST calculations.

References

Allen, C.: IEA wind TCP task 37 definition of the UMaine VolturnUS-S reference platform developed for the IEA Wind 15- Megawatt offshore reference wind turbine technical report (2020)

U.S. Department of Energy: Advancing offshore wind energy highlights. Tech. rep., U.S. Department of Energy (2023), https://www.energy.gov/sites/default/files/2023-03/advancing-offshore-windenergy-highlights.pdf, accessed: 2024-07-31.

Jonkman, J., Wright, A., Hayman, G., Robertson, A.: Full-system linearization for floating offshore wind turbines in OpenFAST preprint (2018), https://www.nrel.gov/docs/fy19osti/71865.pdf