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Comparative study of spar-type floating horizontal and vertical axis wind turbines subjected to constant winds

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Abstract

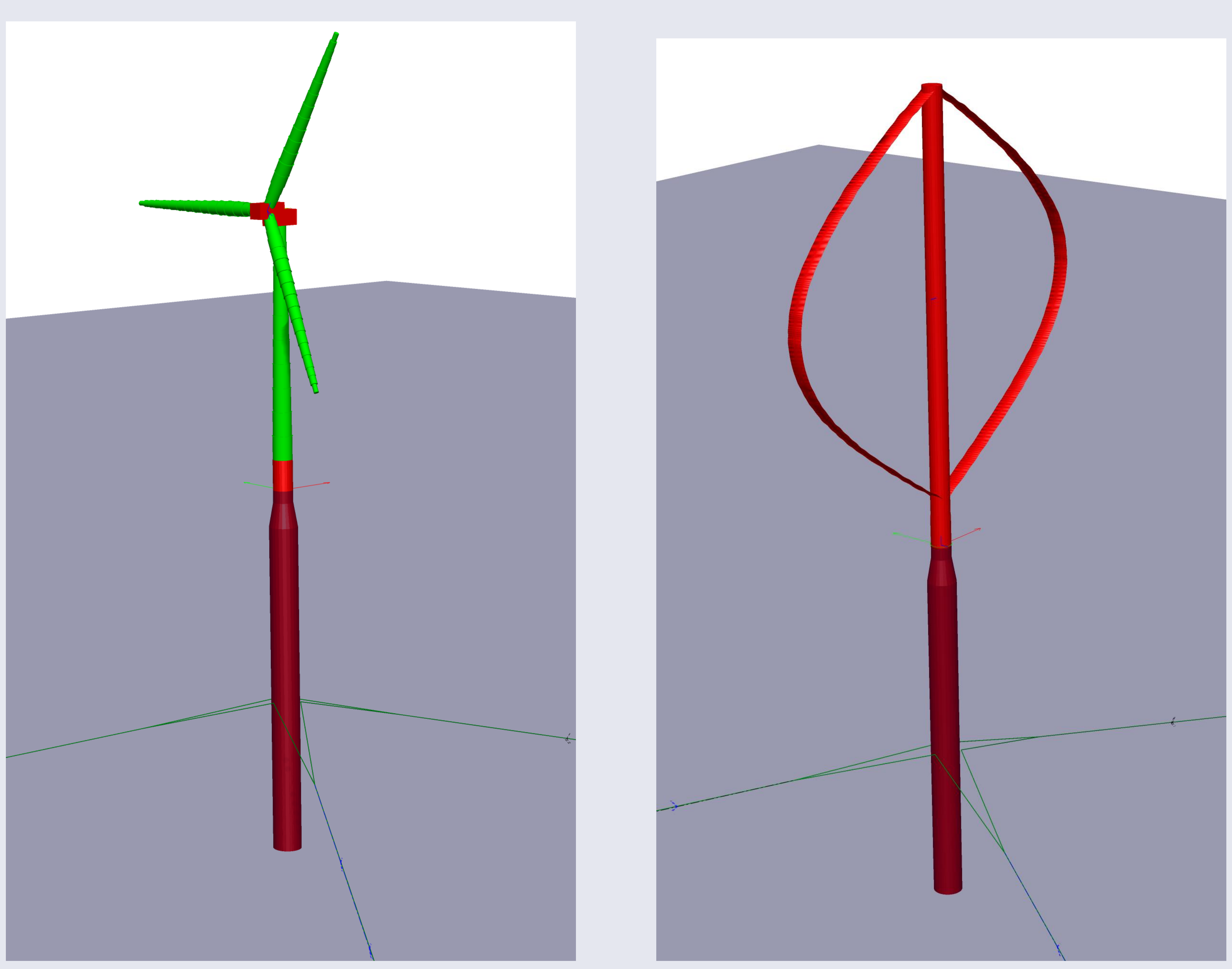
To date the spar-type floating horizontal axis wind turbine (FHAWT) has been widely investigated. Floating vertical axis wind turbines (FVAWTs) are also a promising solution for harvesting wind energy in deep waters. The present study deals with a comparison of a FHAWT with the NREL 5 MW wind turbine and a FVAWT with a 5 MW Darrieus rotor, both supported by the OC3 spar platform. The ballast of the FVAWT spar was adjusted to obtain the same draft and displacement as that of the FHAWT spar. The effect of aerodynamic loads on the rotor performance, motion responses, structural responses and mooring line tension for the FHAWT and the FVAWT were analyzed and compared. Comparative studies show that large 2P aerodynamic excitations exist in the FVAWT and the spar-type FVAWT experiences larger global motions and larger tower base bending moment as compared to the FHAWT.

Objectives

The comparative study aims to illustrate the dynamic response characteristics for the FHAWT and the FVAWT by

1. Comparing the aerodynamic loads acting on the rotor of FHAWT and FVAWT;
2. Studying and comparing the effects of aerodynamic loads on dynamic responses of FHAWT and FVAWT, including platform motions, structural dynamics and mooring line tensions;

Methods



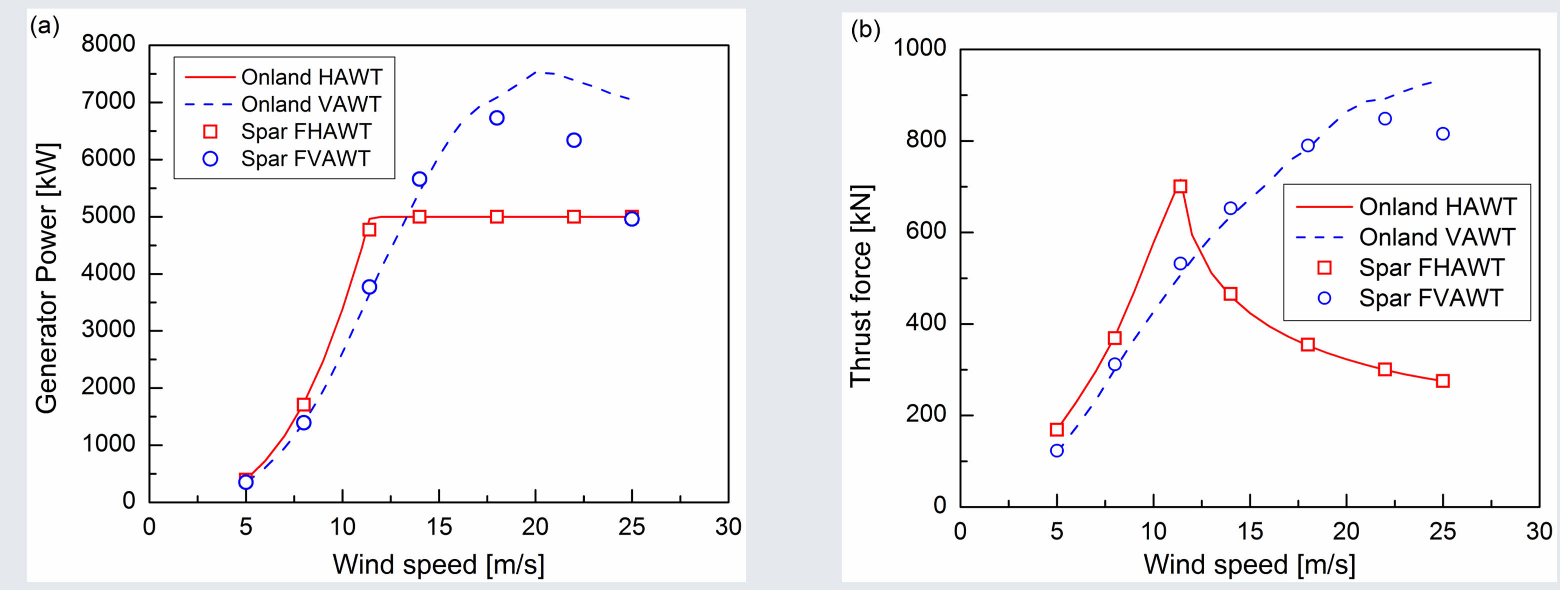
FHAWT: NREL 5 MW WT + OC3 Spar Hull
FVAWT: Deepwind 5 MW Darrieus rotor + OC3 Spar Hull

Two comprehensive aero-hydro-elastic-servo simulation tools, Simo-Rilfex-AeroDyn and Simo-Riflex-DMS, are used to carry out fully coupled nonlinear time domain simulations for the FHAWT and the FVAWT, respectively. They can account for the turbulent wind inflow, aerodynamics, hydrodynamics, control dynamics, structural mechanics and mooring line dynamics.

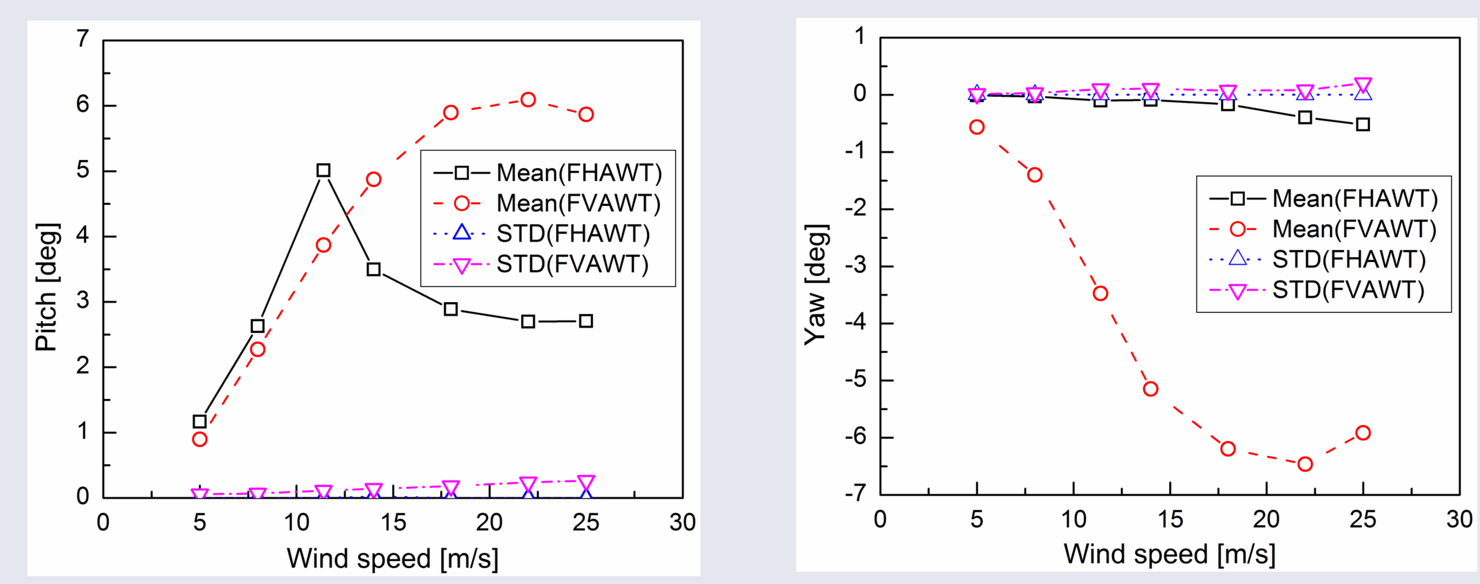
	FHAWT	FVAWT
Simulation code	Simo-Riflex-AeroDyn	Simo-Riflex-DMS
Aerodynamic (aero)	Blade Element Momentum theory + Dynamic Stall	Double Multiple-Stream Tube (DMS) method + Dynamic Stall
Hydrodynamic (hydro)	Linear Potential Flow + Viscous Force by Morison Eq. + Diff. Freq. Force by Newman Approximation	
Structural dynamic (elastic)	Nonlinear FEM	
Control system (servo)	Generator Torque Control and Blade Pitch Control (in Java)	Generator Torque Control (in Java)

Results

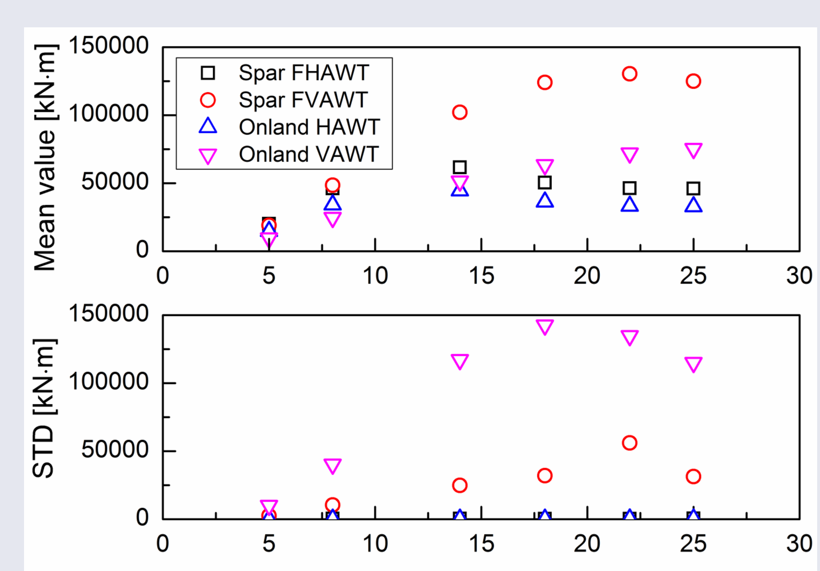
Wind Turbine Performance



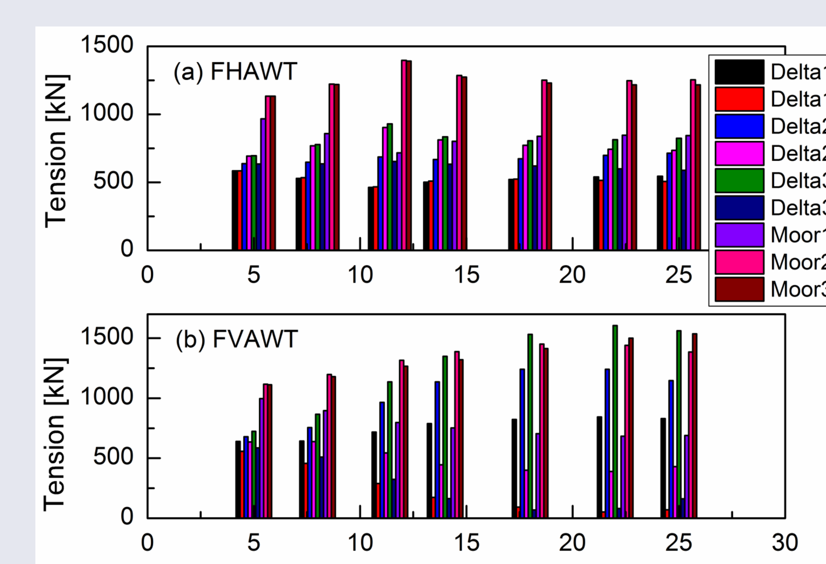
Platform Motions



Tower Base Fore-Aft Bending Moment



Mooring Line Tensions



Conclusions

- The aerodynamic loads acting on the 2-bladed Darrieus VAWT show significant 2P variations, while the aerodynamic loads acting on the 3-bladed HAWT illustrate small 3P fluctuations. For VAWT, these 2P aerodynamic torque variations can be mitigated by increasing the blade number or using helical blades, which will be studied in the future.
- Large discrepancies exist in the generator power, thrust force and torque for the FVAWT and the FHAWT due to the different aerodynamic load characteristics and control strategies applied. Non-constant generator power output at above rated wind speeds for the FVAWT exists and its effects on grid connection may be alleviated when the FVAWTs are deployed as wind farm. Moreover, a more robust controller will be developed to improve the generator power performance.
- The spar-type FVAWT exhibits large global motion responses, especially in surge, pitch and yaw, at high wind speeds as compared with the spar-type FHAWT. The tower base bending moment of the FVAWT is much larger than that of the FHAWT as well. Moreover, the tower base fore-aft bending moment of the FVAWT has larger mean values and smaller variations when compared to the landbased VAWT, indicating that floating support structure can alleviate the structural responses due to the 2P excitations. For the FVAWT large variation exists among the mooring line tension at high wind speeds, and the current mooring system is only sufficient for the operational wind speed.

References

1. Wang K, Luan C, Moan T, Hansen MOL. Comparative Study of a FVAWT and a FHAWT with a Semi-submersible Floater. Proceedings of the 24th International Ocean and Polar Engineering Conference. Busan, Korea. 2014.
2. Schmidt Paulsen U, Friis Pedersen T, Aagaard Madsen H, Enevoldsen K, Nielsen PH, Hattel JH, et al. Deepwind-an innovative wind turbine concept for offshore. European Wind Energy Association (EWEA) Annual Event. Brussels. 2011.
3. Vita L. Offshore Floating Vertical Axis Wind Turbines with Rotating Platform. Roskilde, Denmark: Technical University of Denmark. 2011.
4. Jonkman JM, Butterfield S, Musial W, Scott G. Definition of a 5-MW reference wind turbine for offshore system development. Tech. Rep. NREL/TP-500-38060, NREL, Golden, CO, USA. 2009.
5. Wang K, Moan T, Hansen MOL. A method for modeling of floating vertical axis wind turbine. Proceedings of the 32th International Conference on Ocean, Offshore and Arctic Engineering. Nantes, France. 2013.