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Investigation of the Floating Offshore Wind Turbine Blade Deformation in a Two-way Fluid-Structure Interaction

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Abstract

This research includes aeroelastic simulation of a floating wind turbine blade in pitch and surge motions. In this investigation, NREL 5MW wind turbine supported by a spar-buoy platform has been utilised as a validation test case and the results are obtained in minimum, nominal and significant wave conditions. Computational fluid dynamics (CFD) has been coupled with finite element method to solve the flow-field and the structure using fluid structure interaction (FSI) through a two-way coupling. The effect of the tower and platform is ignored. The flapwise and the edgewise deformations are computed and compared with FAST(Fatigue, Aerodynamics, Structures and Turbulence) simulations. The blades exhibit deformations in the Flapwise and less significantly in the edgewise directions when excited by aerodynamic loads. The comparison confirms an overall good agreement, the highest difference was related to significant wave conditions where the predicted maximum power from FSI simulations is about 7% less than the results from FAST.

Objectives

- This simulation provides quantitative information about the aeroelastic structural responses as well as the effect of blade deformations on the floating wind turbine performance in three different wave conditions.
- The innovative FSI technique uses an iterative two-way interaction of high fidelity CFD and FE(Finite Element) Ansys software.

Methods

Computational domain includes a stationary and a moving part. Reynolds-averaged Navier-Stokes (RANS) equations were applied along with the k- ω Shear-Stress transport (SST) turbulence model. Surge and Pitch motions are implemented in moving section. A dynamic meshing strategy has been developed implementing the structural deformation to fluid domain that includes a total number of 14.2 million cells. The elastic behaviour of the turbine rotor blades was simulated adopting a structural model in Ansys Transient Structural solver. Load calculations of CFD and structural deformation information are exchanged in a two-way communication in a time step and CFD calculations are modified based on the feedback from structural deformation and this continues until the rotational speed remains unchanged.

Results

In this simulation, a combination of three different wave and wind conditions have been implemented. These are illustrated in tables 1,2.

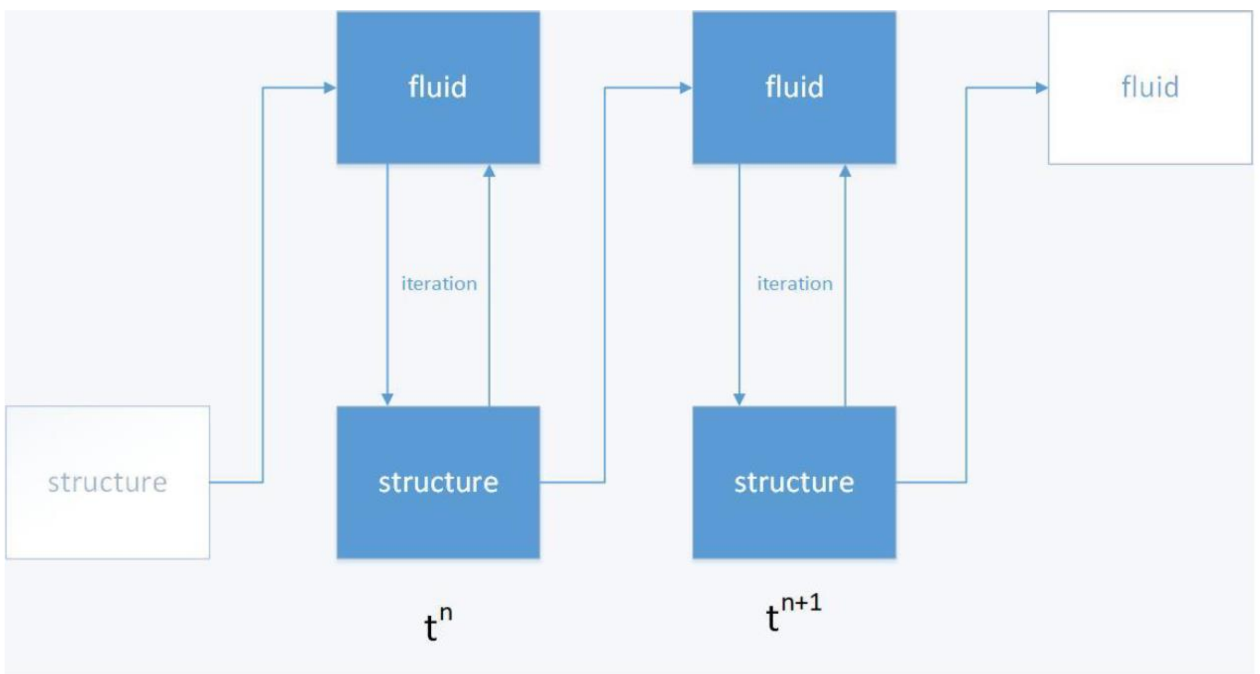
Table 1: Wind and wave data

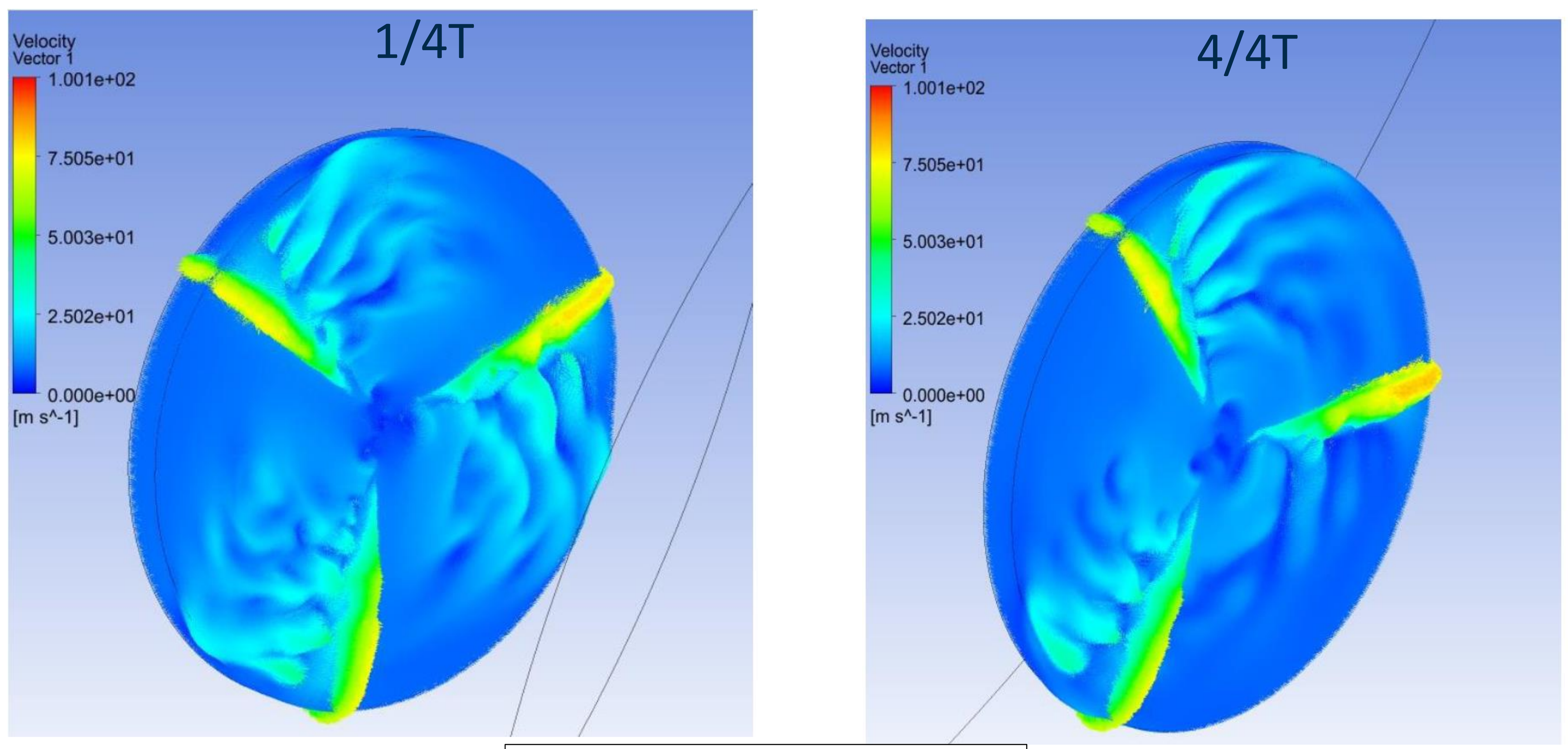
	Condition	$U_\infty(m/s)$	$\Omega(rpm)$	$H_s(m)$	$T_p(s)$
a	Minimum wave	8	9.16	2.5	12.72
b	Significant wave heights	8	9.16	5	8.00
c	Nominal	11.4	12.1	2.54	13.35

Table 2: FAST spar buoy platform motion responses

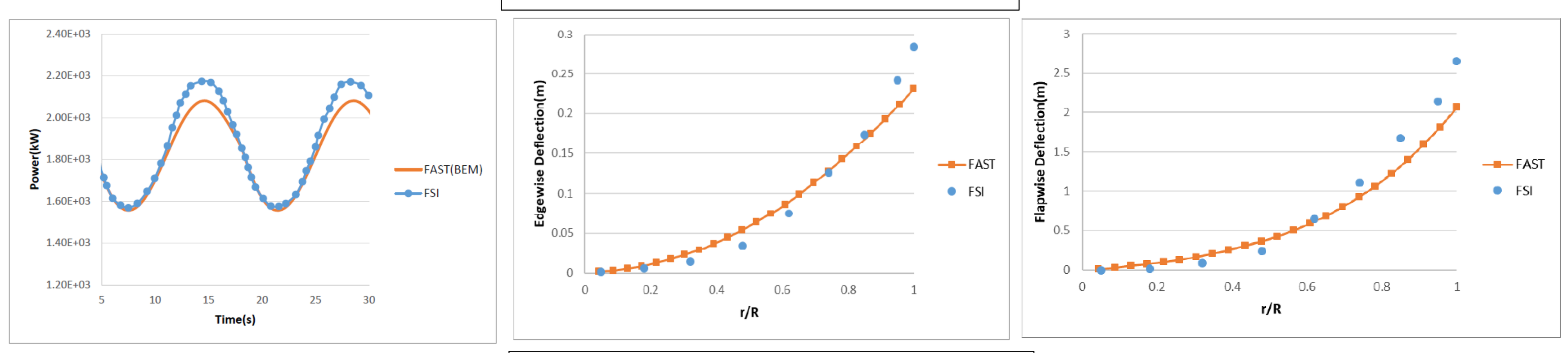
	Condition	Pitch motion amplitude (deg.)	Pitch motion angle (deg.)	Surge motion amplitude (m)
a	Minimal	0.34	2.5	0.7
b	Significant wave heights	0.36	5.0	0.65
c	Nominal conditions	0.49	5.0	1.14

Minimum power occurred when platform experienced highest level of changes in the pitch and surge amplitudes The power maximum peaks occurred when wind turbine moved against the wind direction. During this motion, wind turbine experience smaller change in the rotational speed and therefore less significant separation in the trailing edge. The highest amount of difference between FSI and FAST was observed at peak values which are about 4%, 5% and 7% for minimum, nominal and significant wave conditions respectively. Unlike CFD, blade element momentum (BEM) used in the current version of FAST is incapable of predicting the effects of the dynamic wake interference with the rotor. Blade deflections are examined in 0.25T where pitch and surge amplitudes are maximum. As expected the maximum deflection occurs at the tip of the blade.

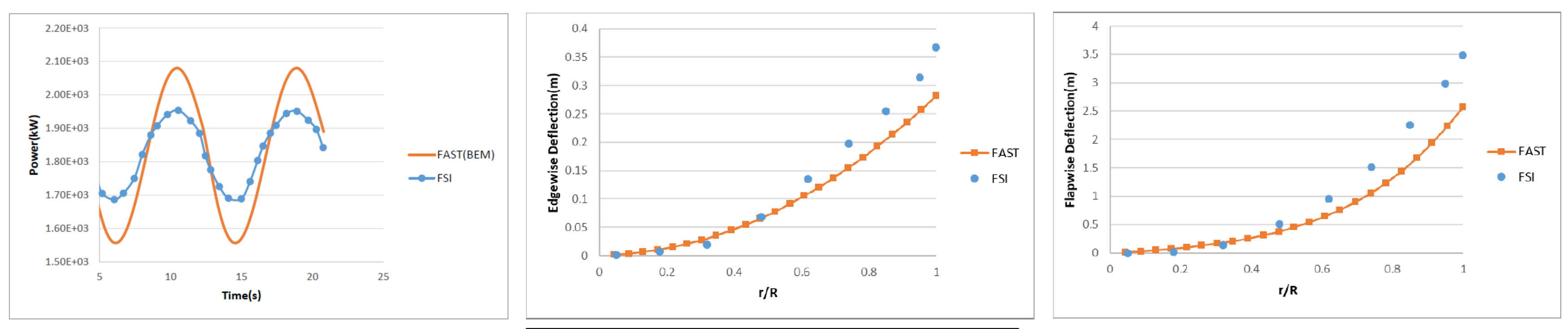




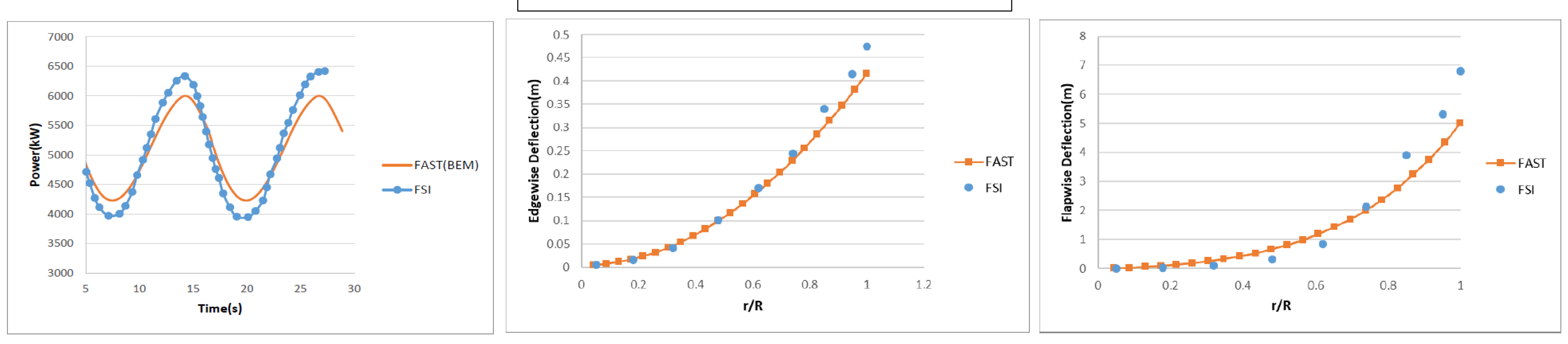
(a) Minimum wave conditions



(b) Significant wave conditions



(c) Nominal wave conditions



Conclusions

In this study, the aeroelastic behaviour of a floating offshore wind turbine in pitch and surge motions was examined using an iterative two-way FSI coupling. The results included power as well as aeroelastic deformations in Flapwise and Edgewise directions. FAST and FSI tend to have a different estimation of the power in the peak area in which platform achieves a maximum motion velocity. The same trend was observed in the blade deflections of Edgewise and Flapwise deflections where FAST under predicts the deformations and over predicts the power generated.

References

1. Kaviani, H. Nejat, A., 2021, Investigating the Aeroelasticity Effects on Aeroacoustics and Aerodynamics of a MW-class HAWT, Journal of Wind Engineering and Industrial Aerodynamic, 213(104617) .
2. Kim, H. & Tran, T., 2015. The Platform Pitch Motion of Floating Offshore Wind Turbine: A Preliminary Unsteady Aerodynamic Analysis, Journal of Wind Engineering and Industrial Aerodynamics , 142, 65-81.
3. Kim, Y. & Kwon, O., 2019. Effect of Platform Motion on Aerodynamic Performance and Aeroelastic Behavior of Floating Offshore Wind Turbine Blades, Energies Journal, 12(2519).
4. Moriarty, P. & Hansen, C., 2005. AeroDyn Theory Manual, Technical Report NREL/EL-500-36881, Golden, National Renewable Energy Laboratory.