Journal of Mines, Metals and Fuels, 71(1): 40-44; 2023. DOI: 10.18311/jmmf/2023/33353

Print ISSN : 0022-2755

Journal of Mines, Metals and Fuels

Contents available at: www.informaticsjournals.com/index.php/jmmf

Dynamic Modelling and Modal Analysis of an Offshore Wind Turbine

S.L.N. Vishal and Chandrasekhara CV

*Department of Mechanical Engineering Pes University, Bangalore, Banglore 560085, India. *E-mail: slnvishal27@gmail.com*

Abstract

Floating wind turbine is one of the promising technology due to its consistent and powerful wind sources in deep-sea zone resulting in high power generation. In the present study a 5 MW baseline spar-type offshore wind turbine is considered for modelling and modal analysis. Sub-systems viz., rotor, nacelle, supporting tower, platform and mooring lines are developed using Ashes software. Commercial software which is specially dedicated for the analysis on onshore and offshore wind turbine. Structural steel is considered for the material properties of the sub-systems. Considering the wind speed and wave effects on the live conditions, modal analysis is carried out. The natural frequencies up to six modes and respective mode shapes are established and reported.

Keywords: *Floating offshore wind turbine, Modal analysis, Natural frequency, Mode shapes, Ashes*

1.0 Introduction

Floating offshore turbine (FOWT) designs are being put out using the same floating platforms principles that are typically employed for the offshore oil and gas sector. An abundant supply of inexpensive energy may be found in ocean energy harvesting. The separation energy is maximized by mounting wind turbines on floating platforms out at sea, where the wind is more consistent and powerful.

Installed the 5-MW offshore wind turbine on a floating spar platform is modelled with a hybrid method of finite element MBS using ADAMS, PATRAN, and NASTRAN. The flexible deformation enlarged the motions of surge and pitch by 11.1% and 13.8%, respectively, and had slight influence on the heave motion (Hidekazu et. al 2008). Build a high-fidelity structural dynamic model of a FOWT in which the coupling between the rigid body and the tower elastic motions are considered to formulate the system dynamics (Solihat et, al 2018).

Using a simple model of a wind turbine is constructed with equivalent uncoupled springs providing the foundation response at the pile-cap level. This is used to identify the first natural frequency of the structure interacting with the soil (Shi, et. al (2001). Study investigates the global responses of two FWT with a shared mooring system. Two shared mooring configurations with different horizontal distances between the FWTs are considered (Munir, et.al 2003. illuminate the properties of the differential eigenvalue problem, several classical structures with simple geometry and boundary conditions are considered. It presents an explicit generalization of Lagrange's equations, (Jhinkins et.al 1993). Extract the geometrical dimensions of the spar type offshore wind turbine. It gives the complete details of the dimensions of the system and further work is carried out on the improvement of the system. (Jonkmans et.al 2009).

In the present study a 5 MW baseline spar-type offshore wind turbine is considered for modelling and modal analysis. The sub systems like rotor, nacelle, supported tower and baseline platform are developed in the commercial software with the dimensions.

**Author for correspondence*

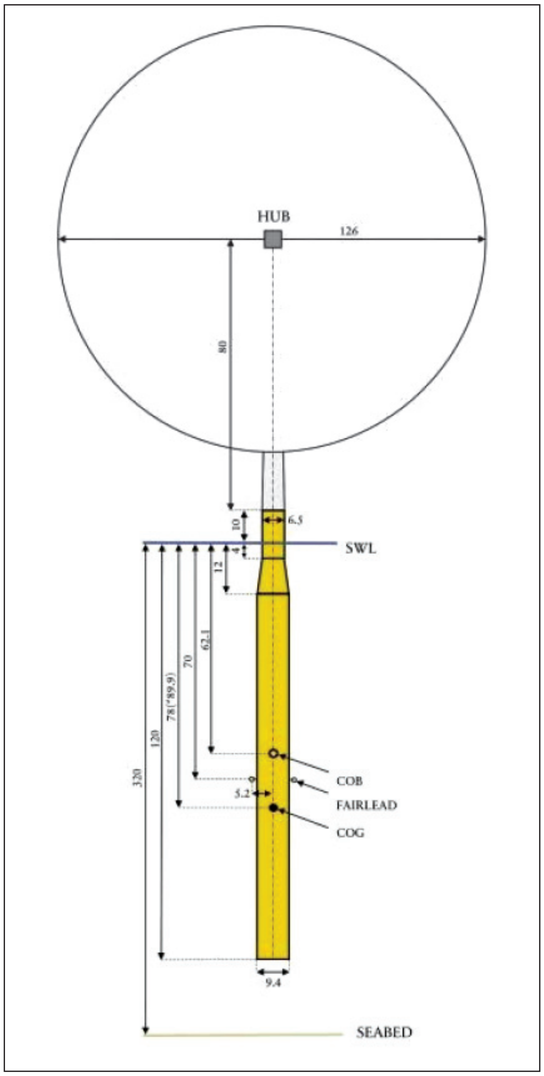

Figure 1: Model of fowt

2.0 System Description

2.1. OC_3 Hywind Platform

The implementation method is carried out by taking the conventional OC_3-Hywind Phase IV spar buoy design as a specialized floating platform. The OC_3 architecture was chosen primarily because it has been extensively examined over the years, and data for code-to- code comparisons and quality checks are abundant in the literature. The baseline OC_3 Hywind shape is shown in Figure 1.

COB stands for the center of buoyancy, whereas COG stands for the center of gravity. The platform top (tower base) rises 10 meters above sea level (SWL). In the SWL zone, when only the platform and ballast are present, the distance between SWL and COG is approximately 89.9 m.

The geometrical parameters are the initial step to take forward of the project work which gives the complete strength of the dimensions of the system. Modelling is an important part of understanding the structure of a system. The developed models are used for the analysis for constructing a real model by providing realistic boundary conditions. modelling is done with the help of numerous tools in the software with the dimension.

The tower is attached to the buoy 10 m above the water surface which causes the top of the tower and rotor to be at a height of 87.6 m above the sea level. This dimensioning allows for sufficient clearance between the blade tips and extreme wave heights. The steel tower has a diameter of 6.5 m and wall thickness of 0.027 m at the base. Both of these dimensions taper to 3.87m and 0.019 m at the top. The mass of the tower is 249,718 kg, which includes any additional weight from paint, bolts, welds, and any other components. The rotor has a mass of 110,000 kg and the nacelle has a mass of 240,000 kg.

Number of lines 3 depth of connection at buoy 70m depth of connection at anchors 320m angular. The mooring system consists of three cables that are equally spaced around the buoy. They are attached to the structure 70 m below the water surface and then anchored to the seafloor. In this specific design, the ocean depth has been assumed to be 320m. The cables extend outward to a radius of 853.9 mat the connection to the seafloor. The lines have an initial unstretched length of 902.2m and a diameter of 0.09 m

The structure being analyzed is known as the OC_3-Hywind concept and was designed by the National Renewable Energy Lab (NREL) (shown in Table 1).

Table 1: Properties of fowt (Jonkmans et, al 2008)

Dimensions	Units	Values
Rotor diameter	m	126
Hub height	m	90
Rotor mass	Kg	$110*10^3$
Nacelle mass	Kg	$240*10^3$
Tower mass	Kg	$347.7*10^3$
Cut-in, rated, cut-out wind speed	m/s	3,11.4,25
Rated rotor speed	m	6.9,12.1
Length	m	120
Top diameter	m	6.5
Bottom diameter	m	9.4

2.2 NREL Offshore 5Mw Baseline Wind Turbine

Wind turbine specifications are based on the NREL offshore 5 MW baseline design which is widely used in literature as reference design. The wind turbine has a diameter of 126 m and it is located at the top of the tower. The hub height from the SWL is about 90 m.

3.0 Software Introduction

Ashes is the commercial software designed for doing analysis on the wind turbines.

The types of wind turbine are simulated as follows:

- Onshore
- Offshore

1. Monopile
2. Semi-submersible
3. Spar floater

Since Newton's second law and the FEM are used, the structure will respond to the elite dynamic loads (changing in time) applied to it and how it responds (how it moves and deforms) will depend on stiffness (flexibility), mass, and damping properties. A static analysis is performed, where all velocities, accelerations and inertia forces are zero The parameter rotor model is visible. Specific types as monopile, semi-submersible, spar type can be designed and analysis can be carried out through a various properties like speed tip ratio, motions of the turbine, generation of power can be seen graphically.

3.1 Design of Spar Type Wind Turbine

In the Ashes module settings, we offer the main features of the simulation, choose the fixed support faces, and the final setting is shown in Figure 2.

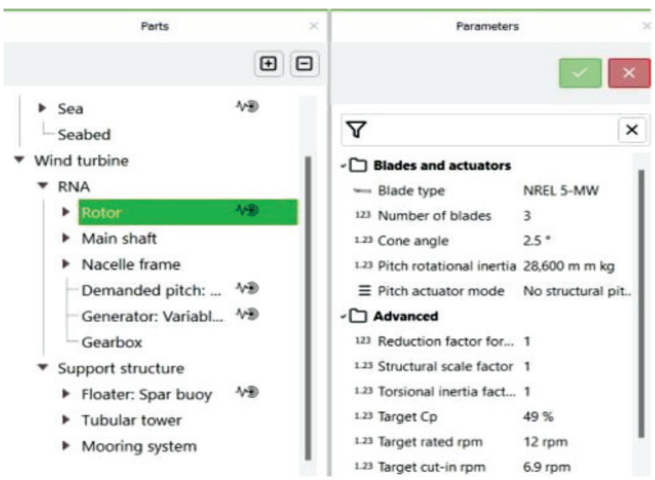

Figure 2: Parameter settings

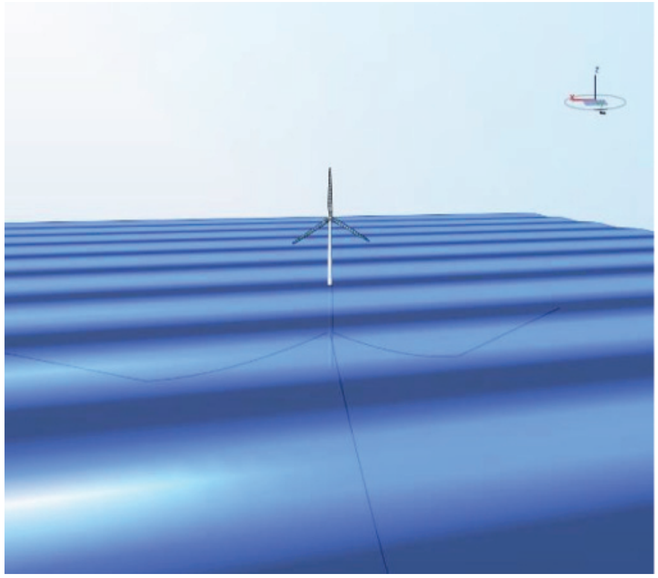

Figure 3: Floating offshore wind turbine

In the floater settings like designation of the material, elevation of the height (base and top), ballast settings, spar buoy settings like upper diameter, lower diameter, thickness fairlead distance are applied. From the tubular tower settings like giving material from above water level height base diameter of the tower (above and the below) and the thickness. In the rotor settings like type of the blade, number of blades its cone angle and reduction factor cut-in speed and the cut-off speed is to be given and the applied settings.

The nacelle settings of the generator, gear box settings are applied here in the generation of the power from the rotation of the blades by keeping the cut in speed and the cut off speed in view and in the simulation analysis settings is kept to be varied but in the eigen analyses RNA settings are applied as default.

3.2 Dynamic Characteristic Extraction

The initial stage in Ashes modal settings is to provide the simulation analysis settings, followed by the fixed support faces. After all of the parameters have been completed, designers can examine how the system behaves at different frequencies based on the data supplied. The mode shapes are shown in Figures 4 to 9.

In the 3rd mode shape represents the third natural frequency of the system at 0.033 Hz.

In the 4th mode shape represents the fourth natural frequency of the system at 0.040 Hz.

The 5th mode shape represents the fifth natural frequency of the system at 0.047 Hz.

The 6th mode shape represents the sixth natural frequency of the system at 0.059 Hz.

The natural frequencies for offshore wind turbine spar type system are obtained from ASHES software. After running of simulation for the spar type wind turbine for extracting of dynamic characteristics six mode shapes are obtained and it is presented in the Table 2.

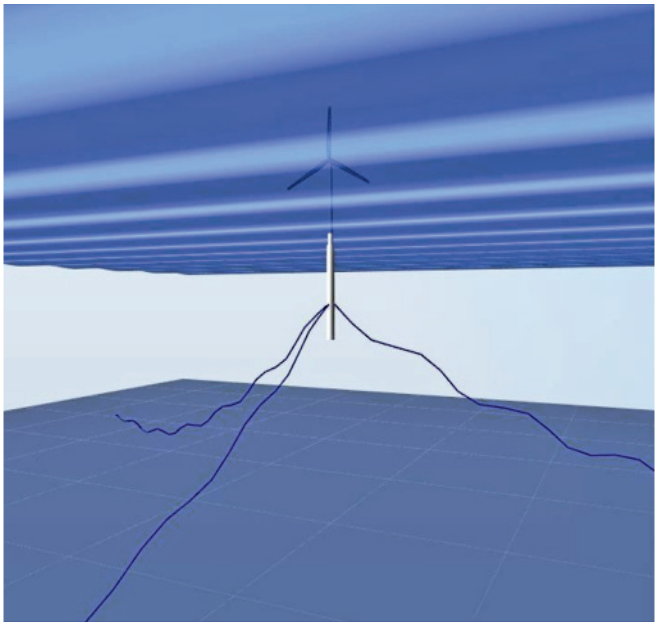

Figure 4: 1st mode shape

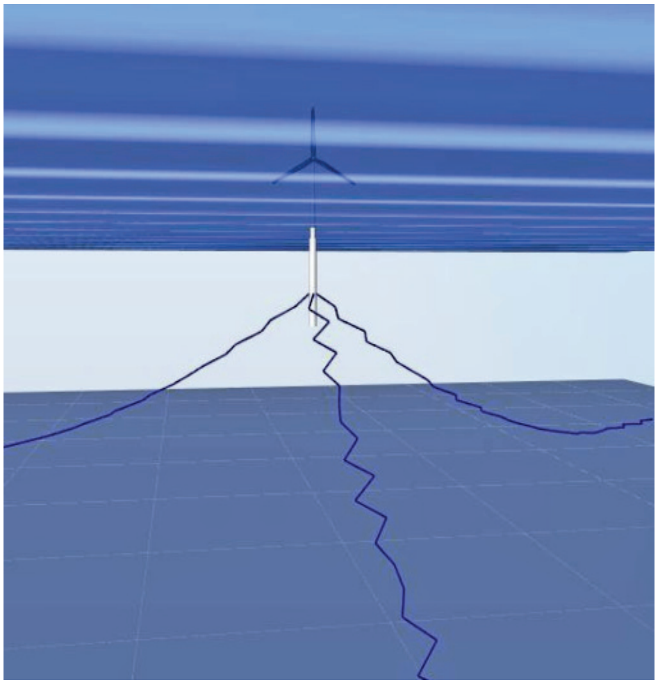

Figure 5: 2nd mode shape

Table 2: Results obtained from ashes

Mode shapes	Frequency [Hz]
1	0.011
2	0.024
3	0.037
4	0.046
5	0.058
6	0.064

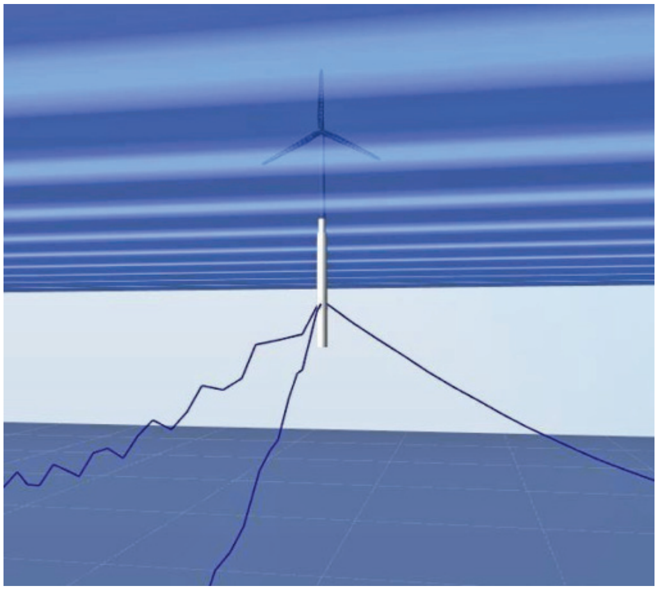

Figure 6: 3rd mode shape

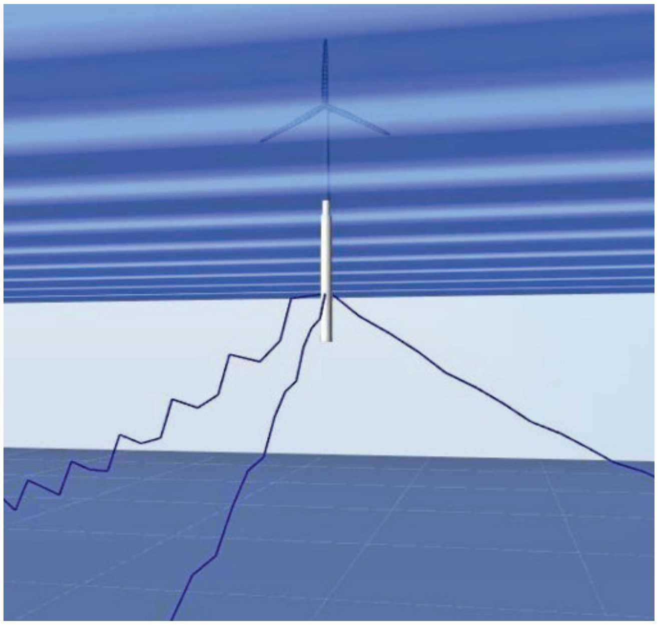

Figure 7: 4th mode shape

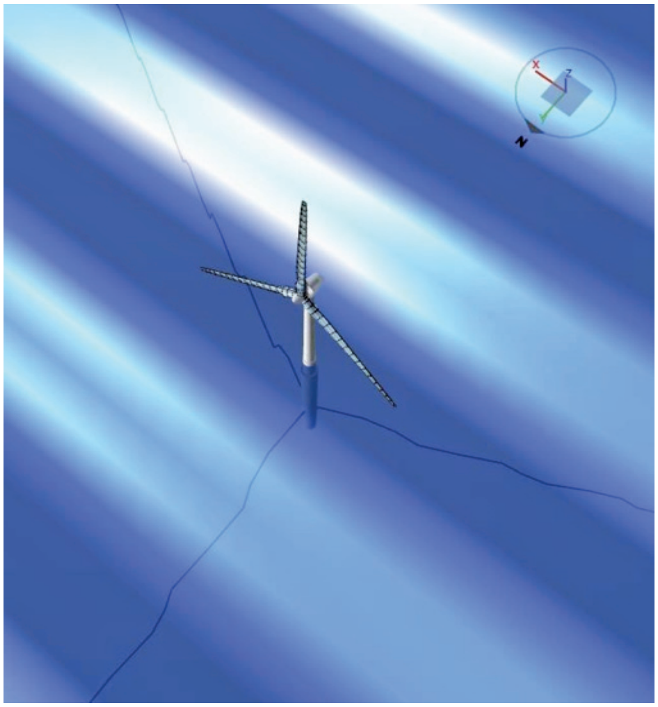

Figure 8: 5th mode shape

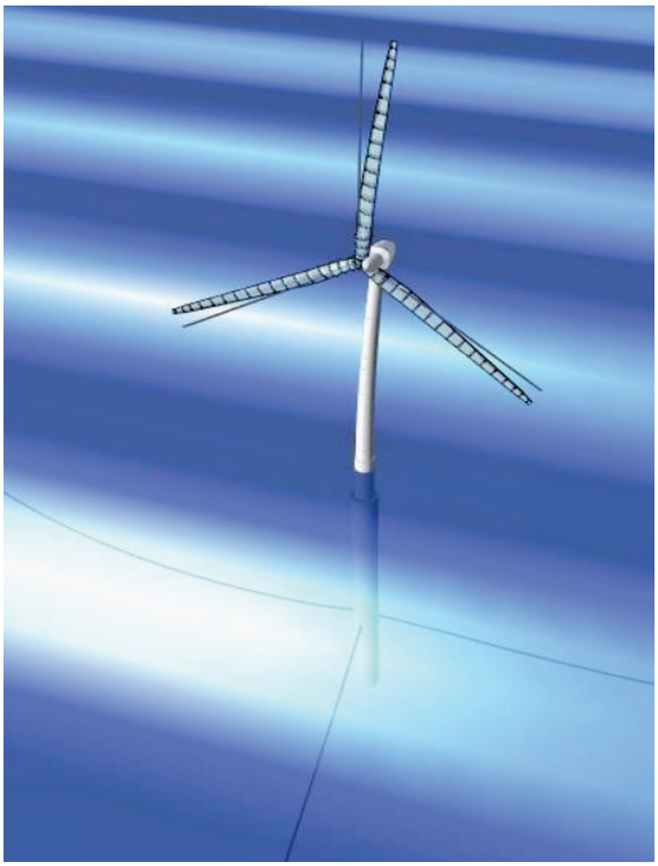

Figure 9: 6th mode shape

4.0 Conclusions

Mode shapes are used to see at natural frequency how the system is responding, here six natural frequencies are obtained, at the 1st mode shape one of the mooring lines is getting oscillating, in the 2nd mode shape two mooring lines are getting excited, in the 3rd three mooring lines are vibrated, in 4th mooring lines are getting oscillated extremely, in 5th combination of the blade and the mooring lines and in 6th mode combination of all had taken place.

- The first six natural frequencies are getting excited to the mooring lines the further natural frequencies are getting excited to the sub systems like blades, supporting tower and nacelle.
- Mode shapes with respective natural frequencies are shown in the figures.
- Designers view the innate frequencies and mode shapes as the most important characteristic of almost every system.
- As one may anticipate, excessive vibrations in any system result in functional and structural problems.
- The natural frequencies of vibration should be calculated when designing a mechanical system to make sure they are much higher than any potential excitation frequencies the system is likely to experience.
- Numerical analysis is done in the commercial software Ashes.

References

1. Al-Solihat, M. K. and Nahon, M. (2018): Flexible multibody dynamic modeling of a floating wind turbine. *International Journal of Mechanical Sciences*, 142, 518-529.
2. Shi, P., McPhee, J. and Heppler, G. R. (2001): A deformation field for Euler–Bernoulli beams with applications to flexible multibody dynamics. *Multibody System Dynamics*, 5(1), 79-104.
3. Meirovitch, L. and Tuzcu, I. (2003): Integrated approach to the dynamics and control of maneuvering flexible aircraft.
4. Junkins, J. L. (1993): Introduction to dynamics and control of flexible structures. Aiaa.
5. Baruh, H. (2015). Applied dynamics (pp. 5-6 Boca Raton: CRC press.
6. Sarpkaya, T., Isaacson, M. and Wehausen, J. V. (1982): Mechanics of wave forces on offshore structures.
7. Jonkman, J., Butterfield, S., Musial, W., and Scott, G. (2009): Definition of a 5-MW reference wind turbine for offshore system development (No. NREL/TP-500-38060). National Renewable Energy Lab.(NREL), Golden, CO (United States).
8. Matsukuma, H., and Utsunomiya, T. (2008): Motion analysis of a floating offshore wind turbine considering rotor-rotation. *The IES Journal Part A: Civil & Structural Engineering,* 1(4), 268-279.