Offshore Wind Turbine Foundation Design as per Indian Conditions

Soorya Udayabhanu[1], Jerin Mathew George[2]

[1](Department of Civil Engineering, Amal Jyothi College of Engineering /MG university Kerala, India)
[2](Department of Civil Engineering, Amal Jyothi College of Engineering /MG university Kerala, India)

Abstract: *Wind has been used as a source of energy since the early middle ages. Initially, windmills were used for mechanical purposes such as the milling of grain and the pumping of water. The modern wind turbine however converts the energy extracted from the wind to electrical power which can be used elsewhere. There are different types of foundation in different water depth for offshore wind turbine. Generally in India, production of wind power plant has not yet established. In this study, a location at West Cost of India has been selected. The system consists of pile, turbine tower and soil modeled as 3D finite element model in ANSYS. In this paper, Preliminary design of monopile and tripod has been done to determine the pile length the as per Indian offshore condition is designed and the lateral performance of monopile and tripod supported wind turbine is determined.*

Keywords: *ANSYS, monopile, Offshore wind turbine, tripod*

I. Introduction

Offshore wind power consists of construction of wind farms in bodies of water to generate electricity from wind. Better wind speeds are available at offshore compared to land, so offshore wind power's contribution in terms of electricity supplied is higher. The wind out at sea can be up to 40% more frequent and regular than on land. Offshore wind farms built to the same capacity as onshore farms are more productive. However, offshore wind farms are relatively expensive. Larger wind turbines can be built, which means that facilities a higher performance. The main disadvantage is that construction costs are high. The cost of building an offshore wind turbine can be twice as much as one on land of equal capacity. The technology behind offshore wind turbines has not yet been developed to its full potential. This means that future projects will be much more commercially feasible than those currently being developed or that are up and running.

Offshore wind is expected to grow massively over the next several decades. Most existing wind farms at sea are in northern Europe, where 5 Giga Watts have been installed. China has started pilot projects (with plans to build 30 Giga watts by 2020), and the United States has many offshore developments in the works (plans for 10 Gig watts by 2020). There are a number of reasons such that expectations are so high for offshore wind. Production of offshore wind power has not been established yet in India. To implement this preliminary studies are needed as per Indian condition. K. Abdel-Rahman *et. al* [1]presented finite element modelling of horizontally loaded monopile foundations for offshore wind energy converters in Germany. Aliasger Haiderali *et.al* [2] studied three dimensional finite element modeling of monopile for offshore wind turbines. Run Liu *et.al* [3] studied behavior of monopile foundations for offshore wind farms in sand. K.Abhinav *et.al* [4] presented uncertainty analysis of offshore wind turbines including effects of soil. Swagata Bisoi *et.a* [5] dynamic analysis of offshore wind turbine in clay considering soil- monopile tower interaction. The present work includes design the wind turbine as per Indian offshore condition, determine the lateral performance of monopile and tripod supported wind turbine.

II. Design Of Offshore Wind Turbine In Indian Offshore Location

A location at West Cost of India has been selected based on environmental data obtained from National Renewable Energy Resources (NRELT [4]. Soil profile mainly consists of sand and a few layers of silt and clay .Soil behaves as an elasto-plastic material so it is modeled as Drucker - Prager model. The Drucker–Prager yield criterion is a pressure-dependent model for determining whether a material has failed. The material of turbine tower, monopile and tripod is steel and the strength properties are modulus of elasticity, Poisons ratio and density. Turbine tower with height 81m and, Diameter (D) of monopile is 6m .Diameter for tripod is 3m.
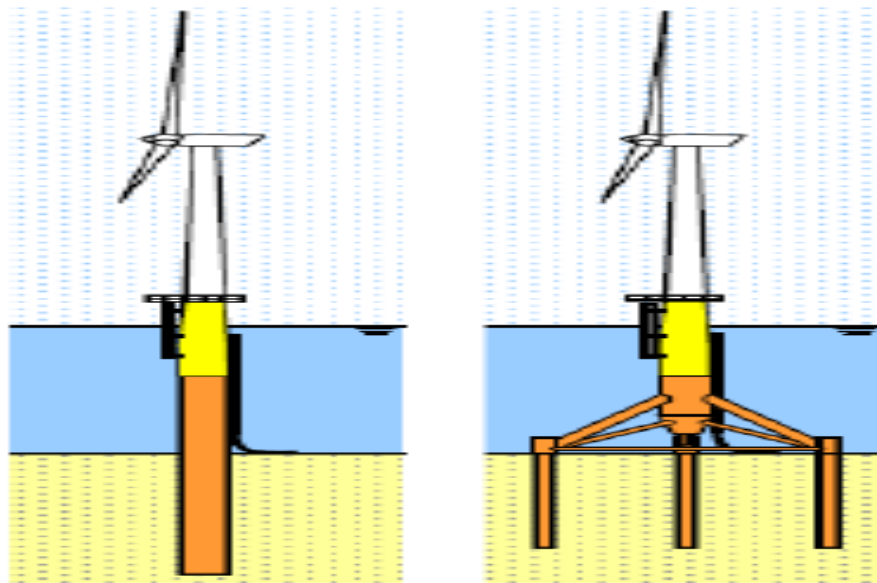
Fig 1: Monopile and Tripod Supported Offshore Wind Turbine

III. Loads On Turbine Tower

3.1 Wave Loads

For the calculation of the wave loads, the Morison formula for slender structures is used, as proposed in the DNV Offshore Standard. This load consists of two parts: an inertia part that is caused by the acceleration of the water particles and a drag part caused by the flow velocities. The drag and inertia part of the wave load will be 90^0 out of phase. Both forces should be added as vectors for a detailed calculation. In this study this is not taken into account. The formula for the maximum force is given in equation 1.

$$F_{max}=F_I+F_D=C_I K_I H \rho_{water} g \pi D^2/4+C_D K_D H^2 1/2 \rho_{water} r g_D \tag{1}$$

Where, C_I = inertia coefficient

C_D = drag coefficient

K_I = correction for extent of inertia force

K_D = correction for extent of drag force

H = wave height [m]

D = pile diameter

3.2 Current loads

The current velocity will cause a load on the pile under water. This load is not constant under water, but will be highest at the surface level and zero at the seabed due to friction. The load as consequence of the current velocity can be derived using the following formula for flow around slender structures. This formula consists of a static and a dynamic part of the drag force is given in equation 2.

$$F_D=1/2\rho w u2(C_D+C'_D)A \tag{2}$$

Where, C_D = static drag coefficient

C'_D = dynamic drag coefficient

A = area facing flow

IV. Modeling In ANSYS

The ultimate purpose of a finite element analysis is to recreate mathematically the behavior of an actual engineering system. In other words the analysis must be an accurate mathematical model of physical prototype. In broadest sense this model comprises all the nodes, elements, material properties, real constants, boundary conditions and the other features that are used to represent the physical system. The three dimensional model of wind turbine with monopile and tripod are shown Fig 2 and Fig 3. The total deformation of wind turbine with monopile and tripod are shown in Fig 4 and Fig 5. The total deformation of monopile and tripod under soil are shown in Fig 6 and Fig 7. Comparison of monopile and tripod of turbine are given in Table 1.
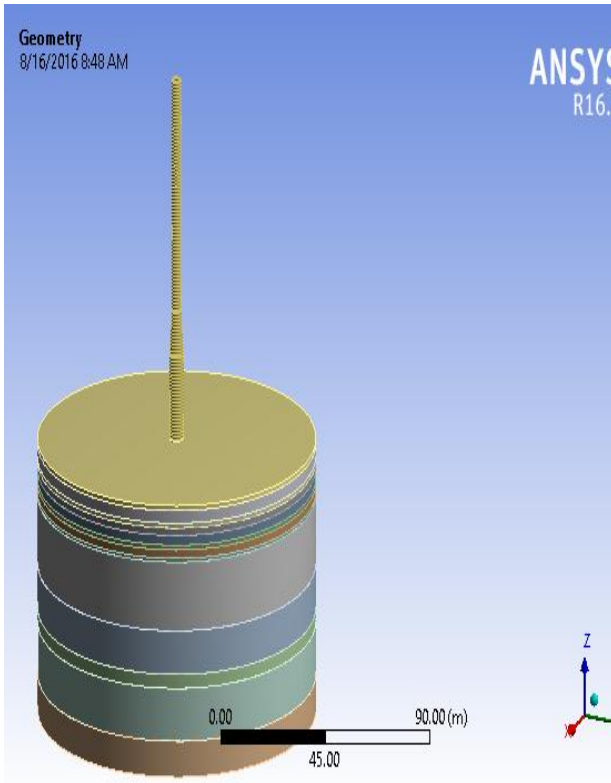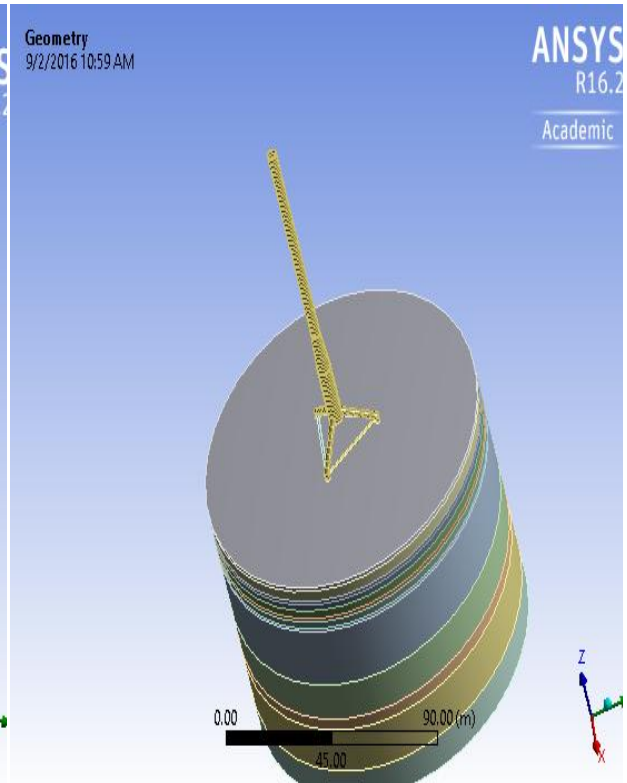
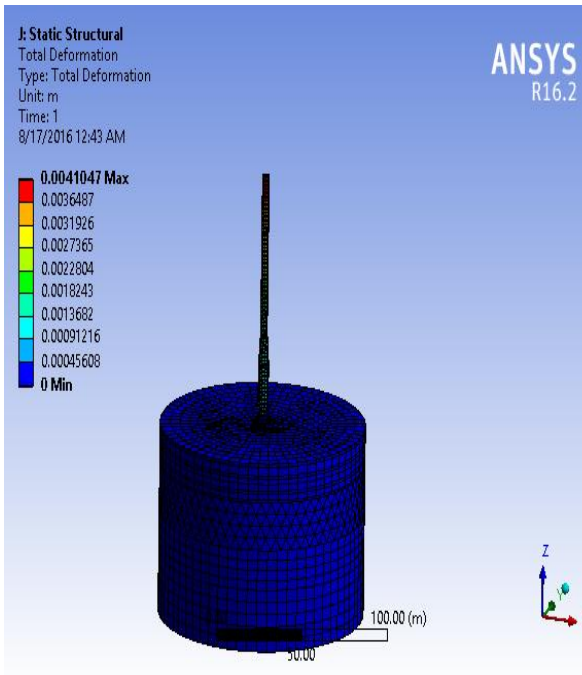**Fig 2:** 3D model of monopile

Fig 3: 3D model of tripod

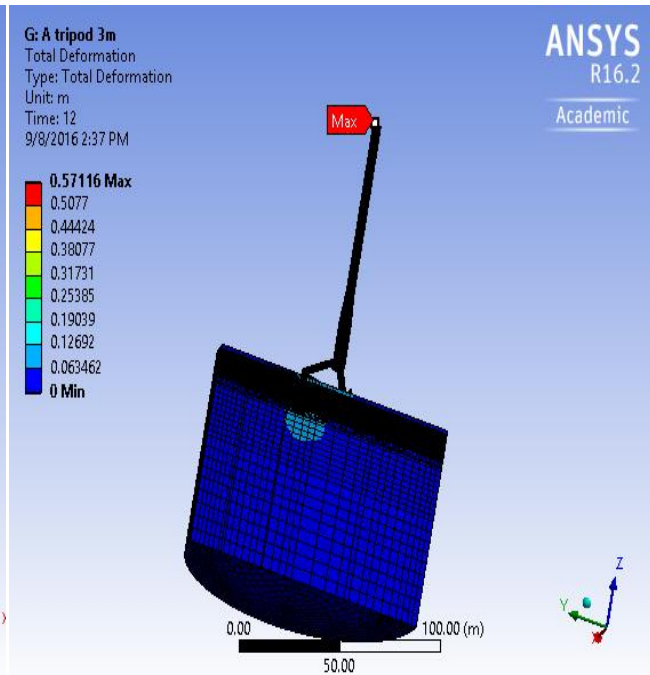**Fig 4:**Total deformation of monopile

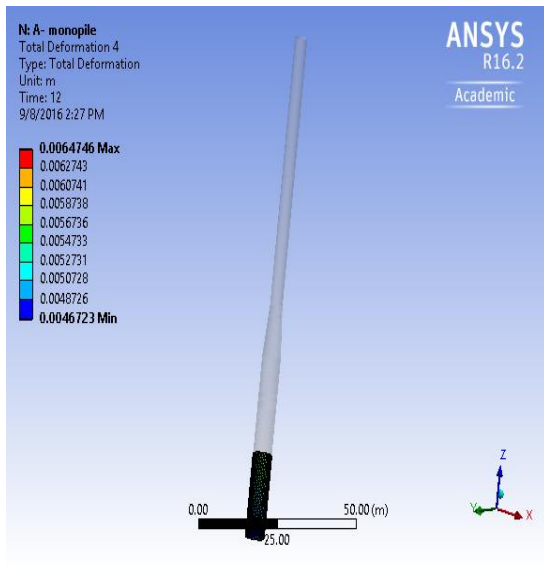**Fig 5:** Total deformation of tripod
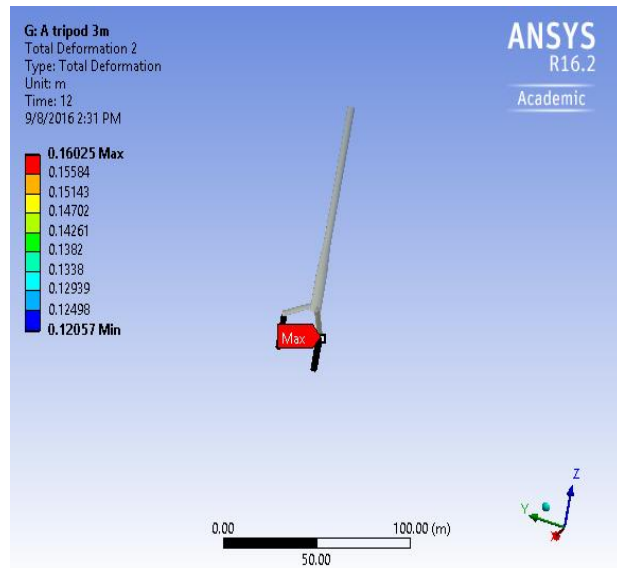
Fig 6: Total deformation of pile under soil (Monopile)

Fig 7: Total deformation of pile under soil (Tripod)

Table 1: Comparison of results

Deformation	Monopile (mm)	Tripod(mm)
Total deformation	0.0041	0.5711
Deformation of pile under sand	0.0062	0.16025

V. Conclusion

In this project it is proposed to undertake a research study on monopile and tripod supported wind turbine in same water depth. Monopile consists of 6m diameter and tripod is of 3m diameter having 50mm thickness. Among the software ANSYS Workbench 16.2 is found to be more suitable.

- Design of monopile and tripod supported wind turbine

A preliminary design has been done to determine the pile length .Design of monopile and tripod is designed in water depth of 25 m by considering wind loads, wave load and current loads. Morisons formula have been used to calculate wave and current loads. In this design, pile length for monopile is 20.47m and pile length for tripod is 16m.

- Lateral performance of Monopile and Tripod supported wind turbine

Lateral performance has been using ANSYS software to determine the deformation. Total deformation in monopile is 0.00410mm and that of tripod is 0.57116 mm which shows that deformation is more in tripod than monopile. Deformation of pile head in monopile is 0.062mm and that of tripod is 0.16025 mm. From the obtained results of pile head it is clear that deformation of pile head is more in tripod than monopile in same water depth.

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