

Review Of Requirement, Design Concepts And Considerations Of Offshore Wind Turbines

Offshore Wind Turbine

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Abstract —The development of wind tower depends on efficient solution being available for a member of technical issue. One aspect being foundation. Foundation choice depends on water depth, sea bed, chara, applied loading, available. Construction technology and economy art. Offshore wind turbine structure (OTWS) may be found on gravity base suction system, monopile and tripod foundation. (The most widely adopted foundation is mono pile, i.e. single large dia. Hollow pole with a estimated 75% of all installed OWT.) This review paper represented most preferable foundation among different configuration support structure found on gravity base cassion. Monopile, tripod and floating foundation.

Keywords- Off shore wind turbine, types of foundation, Configuration of Supporting system

I. INTRODUCTION

The support structure is the main component of the off-shore wind turbine that supports the wind turbine and in combination with suitable foundation transfers all the load to the sea bed and has a crucial involvement to lucrative installations especially in large water depths. Offshore fixed wind turbines which mainly includes mono piles, gravity and tripod foundations are used for shallow water depth of 20-30m and for large water depth like 40-100m research work is in progress where jacket structures are commonly used in the oil and gas sector. There are many site specific parameters that determine the type of foundation and turbines for offshore wind farms. While seabed properties, sea depth, tides, currents, and wave heights determine the type of foundation, the wind profile and the other characteristics of the wind determine the type of wind turbine to select. Offshore installations can be carried on only by special vessels that are designed for such purposes. These vessels must have jack up legs to create a stable working platform at the offshore site in order to lift heavy pieces and install them with a highlevel precision without being affected by the waves, wind and currents.

The installation of a complete wind turbine structure is divided into two stages in general. The foundations and turbines are installed at different times. The installation of the turbine (tower + nacelle + rotor) is done afterward the complete construction of the foundation and the transition piece at the turbine locations.

Structurally a wind turbine consists of six main parts such as tower, nacelle, hub, and three blades. These components of the wind turbine can partly or completely be pre-assembled onshore (in the port) for transporting them to the offshore site. This situation creates many different alternative assembly configurations that can increase or decrease the “transportation and installation” performances.

II. REQUIREMENTS OF OFFSHORE WIND TURBINE

or a similar The design of OWTs has many similarities to those of land based turbines, but there are a number of differences as well as additional considerations such as:

An additional requirement in the design of OWTs is the combined effect of the wind and the waves on the load spectrum. It is likely to be the case that the high winds are accompanied by large waves, but not necessarily that extreme winds are accompanied by extreme waves at precisely the same time. These complex loadings have to be taken into account for designing an OWT especially from a structural point of view [3].

Except some specific application of OWTs, almost all of them are operating as wind farms and are grid connected systems and will be part of a national and possibly international grid network. That is, the generated power should be fed smoothly into the grid so that the required power quality which contributes to grid stability can be achieved [4].

For an offshore location, the poor access and extreme weather condition can postpone the maintenance. Therefore, there is a higher demand for Reliability, Availability, Maintainability and Serviceability (RAMS) in order to decrease the overall cost of generated electricity and make OWTs competitive [5].

Because of a limited time for working offshore due to bad weather conditions and expensive and time consuming logistic and installation activities, there is a higher demand for OWTs to be installed quickly. The environment in which an OWT works is corrosive. Both the salty water and the corrosive air can cause serious failures. The exterior corrosion protection

of the various steel components features a paint system satisfying the standards required for offshore platforms. Interior corrosion. protection requires improved painting systems and maintaining a dry environment inside the machine. To make OWT cost competitive, there is a tendency to harvest more power by manufacturing them larger. This issue presents additional design requirements as the size increases such as transportation and installation problems. These issues present new challenges to an industry that has to date little direct experience of operating offshore and requires new solutions and concepts.

III. WIND TURBINE SUPPORTING STRUCTURES

The concept “support structure” is used to indicate the entire structure below the nacelle which means the support structure consists of a tower and a foundation [17].

The tower elevates the rotor into the air and transfers all the loads to the foundation. The foundation supports the tower, the rotor and the nacelle and resists against loading from wind and waves. Ferguson classifies offshore bottom mounted support structures according to three basic properties that are: installation principle, structural configuration and foundation type [18].

For simplicity, classification of support structures in this paper is based on water depth that each concept can be used economically, and gravity base, monopile, tripod and floating support structures are reviewed.

Support structure	Concept Water depth (m)
Gravity Base	0-10
Monopile	0-30
Tripod	>20
Floating	>50

Table 1: Concepts for support structures

Gravity base structures (GBS)

From structural point of view, a GBS is a monotower that is fixed at the top of a gravity base foundation, Fig. 1.

The foundation consists of a large flat base to resist overturning loads imposed by the wind and wave, and a conical part at the water surface level to break the ice and reduce the ice load by causing the ice sheets to bend downwards and break-up as they contact the conical section [17].

In order to keep the attachment between the GBS and the sea bed, ballasts are laid on the flat base. In this way, the foundation always remains in compression under all environmental conditions and can not be detached from the seabed.

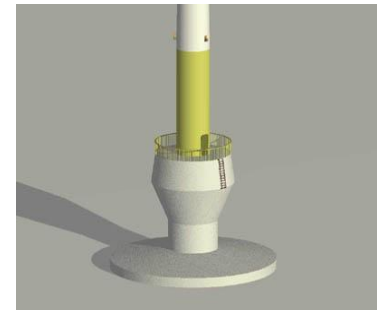


Figure 1: A typical Gravity Base Support Structure [19]

Monopile

The monopile support structure consists of a steel pipe as a foundation which is driven or drilled (sometimes the combination) into the soil. The monopile is equipped with a transition piece to absorb tolerances on the inclination of the monopile and to reduce the assembling time required at sea and the tower which is mounted offshore on the top of the transition piece.

The steel pipe transfers all the loads by means of vertical and lateral earth pressure to the ground.

Therefore, both uncertainties in the ground properties and scour holes can lead to a structure with a quite different structural frequency than designed for. Because of these reasons, designing a monopile support structure is a challenging task.



Figure 2: A typical Monopile Support Structure [19]

Tripod

The tripod consists of a central steel shaft and three cylindrical steel tubes with driven steel piles. The central part distributes the loads to the cylindrical tubes and acts as a transition piece for the tower. The cylindrical tubes give additional stiffness and strength and increase the capacity of the structure to support additional overturning moments [17].

The foundation has the advantage that it requires less protection against scour than the monopile, which generally has to be protected against scour in sandy sea beds.

Floating

Current fixed-bottom technology has seen limited deployment to water depths of around 30-m thus far. A floating support structure increases the flexibility in locating the turbine in water depths of up to 200 meters and is well known from oil and gas industry. The floating support structure consists of a floating platform and a platform anchoring system. The platform has a transition piece to install the tower on top of that. The platform can have several topologies such as single and multiple turbine floaters. The anchoring system fixes the platform and can be gravity base, drag embedded, driven pile, suction anchor type [20].

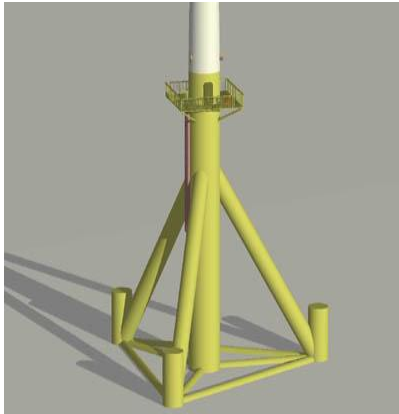


Figure 3: A typical Tripod Support Structure [19]

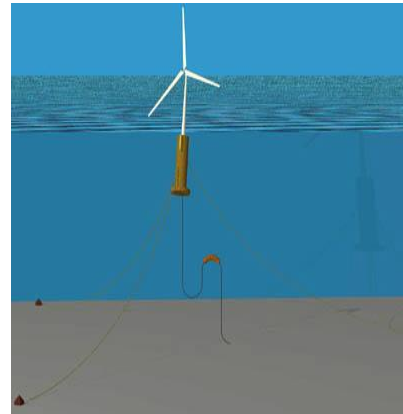


Figure 4: Floating Support Structure [19]

IV. Design Concepts of OTW

An optimum OWT design solution is determined by many factors such as turbine size, soil conditions, water depth and distance from shore. This paper will not explain how to find an optimum design solution for an OWT, but it explains possible design solutions that exist. Particularly rotor, drive train, and support structure concepts will be explained in detail.

Rotor Concepts

There are two types of rotor concepts for horizontal axis wind turbines, upwind and downwind. A downwind configuration allows the rotor to have free yawing and it is simpler to implement than active yawing which requires a mechanism to orient the nacelle with the wind direction in an upwind configuration. Therefore, in an offshore environment where RAMS is a design requirement, a downwind configuration can be matched better with this requirement and gives a higher robustness [6].

Another advantage of the downwind configuration is the reduction of blade root flap bending moment. This can be achieved by preconcing the blades in the downwind direction so centrifugal moments counteract the moments due to thrust forces [7].

The main disadvantage of the downwind configuration is the tower shadow that can cause periodic loads. This periodic load may result in fatigue damage to the blades and may impose a ripple on the generated electrical power; however there is some smoothing effect in the power fluctuations if we consider OWTs as a wind farm [8, 9]. These effects can be decreased by a teetering hub and an individual pitching mechanism while on the contrary these increase the complexity and the associated maintenance. Both upwind and downwind configuration can have one, two, three or even more blades and selection of the number of blades is a trade off among three different points of view that are discussed below:

Operation point of view

Despite higher moment of inertia of three bladed rotors, the main advantage of them is that the polar moment of inertia with respect to yawing is constant while for a two bladed rotor it varies with azimuthal position with the highest amount when the blades are horizontal and the lowest when they are vertical [7].

Performance point of view

In general the optimum tip speed depends on the number of blades and profile type used [11].

The fewer the number of blades, the faster the rotor needs to turn to extract maximum power from the wind. Three bladed rotors have a higher achievable performance coefficient which does not necessarily mean that they are optimum. Two bladed rotors might be a suitable alternative because although the maximum C_p is a little lower, the width of the peak is higher and that might result in a larger energy capture. To achieve this goal a variable speed rotor can be used [7].

Structural design point of view

There is a coupling between tip speed ratio, number of blades and rotor solidity. To be optimum, a high speed ratio rotor should have less blade area than the rotor of a slower turbine. For a given number of blades the chord and thickness decreases as the tip speed ratio increases and this results in an increase in blade stresses [12].

There are some preferences for using a higher tip speed ratio and hence less number of blades in an OWT. Reducing the number of blades reduces the weight of the rotor and subsequently the weight of the support structure. In addition, it shortens the time required for transportation and installation which directly decreases the cost of energy.

Using a higher tip speed ratio also increases the rotational speed and thus reduces the torque on power train and this result in a lighter drive train while the penalty for a higher noise level emission of a high TSR rotor is negligible for an OWT. However a pitch mechanism could be used as an alternative solution or in combination with the variable speed rotor.

V. Colclusion

The many challenges of wind turbine installations in offshore environments (sea and weather conditions) are delineated clearly and balanced with existing and upcoming purpose built turbine installation vessels which are specially designed for overcoming these challenges.

In this study we attempted to and successfully verified all the characteristics of the different kinds of offshore wind turbine support structures while learning about their development. We also identified their respective advantages and disadvantages thus giving us an overview and comparison between these options and thus making it easier and simpler to choose based on different site scenarios. Hence we find out that monopiles are best at shallow depths and the most economical while being easy to install and maintain. Tripods are the most stable choices and have a long life cycle.

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