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Offshore Wind Farms

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ABSTRACT

In Europe there have been many successes with offshore wind farms, since 1991 the installation begun, and there has been 53 European offshore wind farms constructed since. With another ten offshore wind farms under construction, Europe will continue using this source to generate electricity.

Onshore wind farms are successful and used all over the world; however there are disadvantages, such as noise and visual effects, which are eliminated with offshore wind farms. The use of offshore compared with onshore has proven more successful as the turbines and rotor blades are generally much larger than onshore structures and there are less obstructions offshore. There are also stronger winds off the coast, making offshore wind farms ideal.

Offshore wind farms require large foundations and have multiple types that keep them stable in the ocean to withstand high winds and storms. Different foundations are used for varying depths, as well as a sway concept to account for the wave activity from the ocean. The cost to construct these foundations, as well as the turbines, can be quite large, giving offshore wind farms a disadvantage. [1]

The following paper will illustrate the different types of foundations used for various depths of the ocean, how the turbines function, as well as environmental considerations and recovery of the electricity.

1 INTRODUCTION

Europe is leading in the development of offshore wind farms with approximately 53 already in place, and more to come. With the offshore wind farms becoming so popular for generating electricity, the United States of America are beginning to develop their own.

The wind farms are designed to withstand the high wind and waves that are located offshore. There are different types of foundations that can be designed for the wind farms, some which may depend on the depth of the ocean floor. There are several turbines used for a wind farm therefore many foundations must be prepared. Turbines must be placed strategically to optimize the greatest winds to generate power, but also at locations where less underground cable is required.

Offshore and onshore wind farms serve the same purpose, the main advantage of using offshore wind farms are the stronger winds located offshore. Most people would agree that onshore wind farms

are aesthetically unpleasing; therefore, having them offshore and out of site is a plus. Offshore wind farms have become a successful way of generating electricity and will continue improving in the years.

2 DESIGN

The design of offshore wind farms are very complex and have a lot more considerations than then those that are located onshore. The turbines and foundations must be designed for more loads and environmental conditions that would not be a factor for land wind farms. The sea waves, icebergs, and wildlife that are located offshore have a great affect on the design of the foundations and turbines.

2.1 Components

A wind turbine consists of many complex components, some which are located under water and some above. The list of parts that make up the turbine systems are as follows:

1. Rotor Blades
2. Turbine
3. Tower
4. Transition Piece
5. Cable
6. Scour Protection
7. Foundation (ie. monopile)

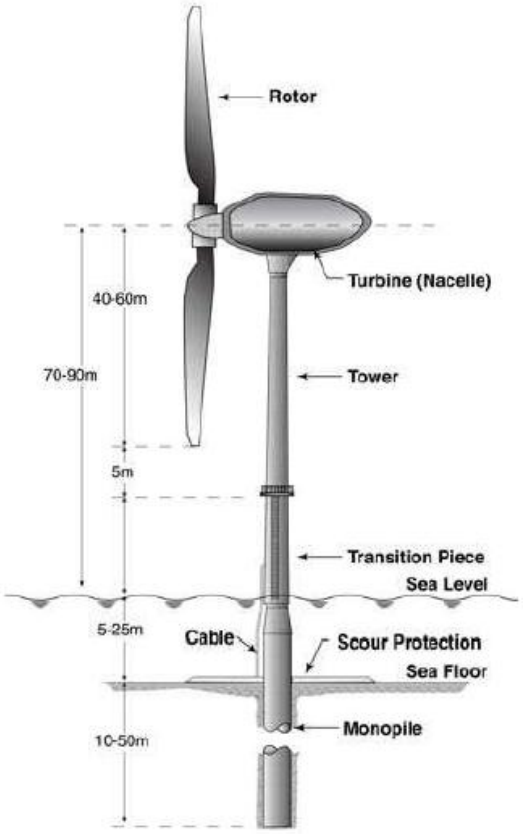

Figure 1 - Components

2.1 Site Selection

The site chosen for an offshore wind farms takes a great amount of consideration. The most obvious consideration is the location with the greatest amount of wind, however, some others that are included are:

1. Distance from shore
2. Proximity to electrical grids, companies and the undersea cables
3. Visibility
4. Disturbance of any routes for airplanes and ships
5. Bird migration flight paths

With these factors considered the design, construction and installation of the wind farms can begin.

2.3 Process

When the site selection has been determined, the design of the turbines and foundations can begin. The conditions at that specific site must be considered for the design as there could be specific environmental conditions such as large amounts of ice or higher wind and wave loadings. A design must be carried out for both the turbine, which will absorb all the electricity generating from the wind, and the foundation which must be designed to resist failure caused by the strong winds and waves.

Once the design has been complete the construction of the turbines and foundations will begin. There are many different types of foundations that can be used for the offshore wind farms and are discussed in the section below. The turbines and rotor blades are large components of the wind farms which are constructed on land and then floated out to the offshore location. At the offshore location they are then hoisted up by a crane and attached to the foundation. The ship used to bring these components out to sea must be stable enough to lift the heavy components; the rotor blades alone can be up to 61.5 meters long and weigh approximately 31,000 pounds. [6]

Figure 2 – Rotor blades brought to site

2.4 Foundations

The foundation for an offshore wind system must be designed to keep the turbine in the correct position and withstand all the forces from the strong winds and waves from the ocean. [2] There can be many different types of foundations used, such as monopile, tripod, or gravity, etc. The depths where the turbines will be placed can influence the type of foundation used. [3] In deep water locations the winds are much stronger than shallow areas closer to shore; therefore more power will be produced further offshore. The typical foundations used are as follows:

1. Gravity - these foundations are typically constructed at a drydock and then floated to the desired location and sunk. The location where the foundation will be placed must have loose soil replaced with stone so the bed is level for the foundation. This type of windfarm has been used for many offshore wind farms in Europe such as the Nysted Offshore Wind Farm in Denmark. [2]
2. Monopile – piles are driven into the seabed using a crane and hydraulic hammer that is attached to the side of a ship. The steel pipe is driven into the seabed at the desired depth and can be used with guy wires if the deflection is too big at greater depths. Piles have a shorter duration then other methods for installation and are the most common method used.
3. Tripods - tripods are used where monopiles and guy wires will not work. It has a triangular shape for stability and is made up of steel pipes. Like the other methods the tripod is constructed on land and then floated to the offshore site for installation. Tripods are used for larger depth as it is not suitable at shallow depths and does not require any preparation of the seabed before installation [8]
4. Braced Lattice Framing – similar idea to the tripod method, the braced framing is made of steel and has more members. This method is quite stiff and can be used at greater depths offshore. [2]
5. Floating Tension Leg – this method is simple to install as it is constructed on land, floated out to site and then the anchors sink to submerge part of the structure. The anchors stabilize the system and keep it in place, and if required, the whole structure can be disconnected from the anchors and floated back to land. This method is not as common as the piles or gravity foundations. [2]

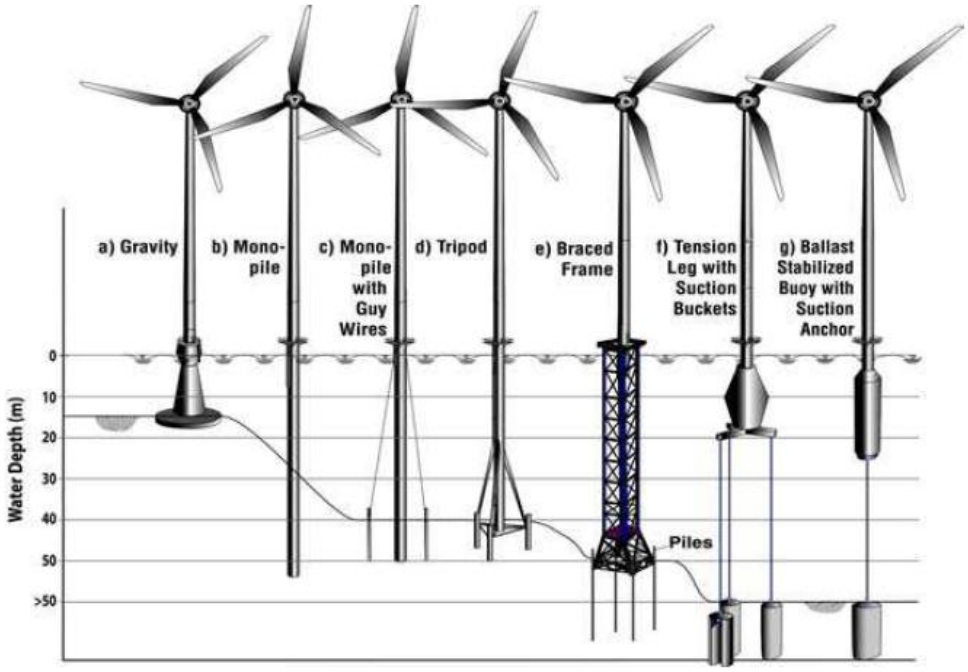

Figure 3 – Offshore Wind Farm Foundations/Various Water Depths

3 ENVIRONMENT & WILDLIFE

There are many wind farms located in European waters, and this poses a problem to the wildlife surrounding these wind farms. Birds and aquatic life are endangered during the installation and operation of the wind farms. During the installation of foundations, the aquatic life can be affected by the noise and the shaking caused by piles being driven or a large gravity wall being sunk onto the seabed. The noise generated from pile driving can greatly affect the marine life living around the location of the new wind farms as they are sensitive to the great amount of noise. This can change wildlife behaviour or potentially cause them to die. As the duration for construction of the wind farms have is short, the effects to wildlife will only be temporary, and the workers try to avoid periods that are crucial to the wildlife, such as breeding or nursing. [2]

Once the wind farms are constructed and in operation, birds are greatly at risk, especially seabirds as their forging and resting grounds may have been taken over. The main reason as to why birds are so greatly affected by the wind farms is because they collide with the rotor blades and die. During migration season, a lot of birds have a specific route, and if the farms are obstructing that route, the birds may collide into them, or will have to find a longer, alternate route. The offshore wind farms are acting as barriers to the birds and displacing them from a preferred route. Offshore wind farm locations are preferred to avoid areas of high bird migration patterns to avoid the decrease in bird population. [4]

Figure 2 – Rotor Blades and Sea Birds
Photo Credit: http://informedfarmers.com/wind-power-impacts-on-wildlife

4 ENERGY RECOVERY

Offshore wind farms have been known to produce a lot more energy than onshore wind farms as the wind capacity offshore is much greater. For example, a wind farms in Denmark, Horns Rev II, has the capacity of generating 209MW of electricity. [7] Offshore wind farms also have much greater turbines than onshore farms with rotor blades capable of spinning a circle 122 meters (400 feet) in diameter [5]. How these large turbines work is that the wind forces the rotor blades to rotate to capture kinetic energy which is then transferred to a rotor shaft which powers an electric generator. The turbine is capable of rotating to capture the greatest amount of wind. The electricity that is produced from the offshore wind farms is transferred to a station offshore or on land through large cables that are buried under the seabed. These cables under the seabed are placed by a procedure called hydro-plowing. This procedure creates a pathway where the cables can be laid, and are buried approximately 2 meters below once the sediment settles. [2] Once the electricity reaches the onshore or offshore stations through the cables, it can be passed through the electrical grid. [5] The further the wind farms are located offshore; the more difficult it can be to place the cables to obtain the electricity.

5 CONCLUSION

Offshore wind farms are a growing source for electricity generation. The uses of these farms are well known in Europe and will soon be starting in the United States. The offshore wind farms have many components and the design must take into account varying loads. Wind and wave loads offshore are much greater than onshore and the foundations must be strong enough to keep the structure stable. The turbines are a very important factor to the wind farms as they capture all the energy and create it into the electricity that is contained on land. With the many offshore wind farms being developed it is clear that this technology is effective and will continue to develop.

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