FOWPI (https://www.fowpi.in/)
FIRST OFFSHORE WIND PROJECT OF INDIA

Project Funded by
European Union (http://eeas.europa.eu/delegations/india/index_en.htm)

Foundation and Structures

Selection of offshore wind structures requires significant technical, financial as well as environmental studies. Broadly these studies include:

- Submarine topography
- Water salinity and its quality
- Hydrodynamic loading
- Aerodynamic loading
- Soil type and its quality
- Mass loading
- Environmental impact
- CAPEX/OPEX, Material availability
- Marine, ports and vessels availability
- Decommissioning plans

Based on such comprehensive investigation, the type of foundation will be selected.

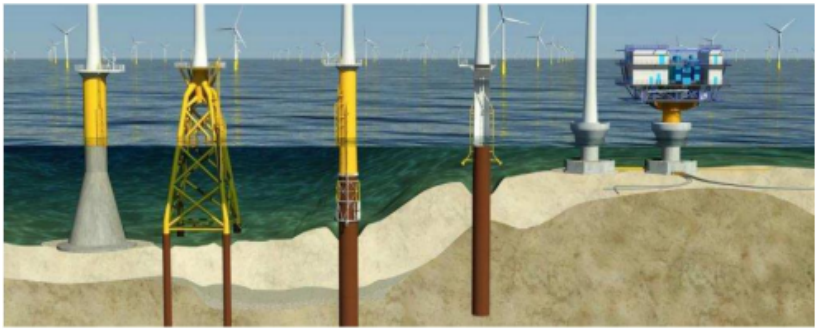
Geotechnical and geophysical investigations along with ground scans are undertaken in order to understand the soil quality and to determine any stratification along with locating any objects in the installation area. These tasks are considered as one of the most significant measures while designing the foundation structure.

Most popular designs for wind offshore structures are monopiles, water jackets, tripods or gravity based foundations. Each structure design has its own merits and strengths.

Monopiles: About 70% of the world wide foundations are monopiles due to its simple and quick fabrication. The installation involves hydraulic hammering of the monopiles into the seabed which is typically 500-800 tons in weight with diameter of 5-6m and 50-60m in length. These types of structures are suitable for sites having a water depth ranging from 0-30m.

Jacket Structures: Typically water jacket structures are four-legged piles with interconnected cross braces having a diameter of about 2m. The base piles are nailed inside the seabed to the adequate depth with the support of pile sleeves. These types of structures are suitable for sites having a water depth ranging from 25-50m.

Gravity Based Foundations: are generally a concrete based structure which consists of sand, rock filled and iron ore filled inside the base and a central steel or concrete shaft for transition to the wind turbine tower. Typically the dead load of the structure is designed to maintain its own stability and strength in water depths up to 60m



(Illustration of OWF foundations designed by COWI. From left: Thornton Bank concrete gravity based, Wikinger jacket (preliminary stage), two times London Array monopile, Nysted WTG and Rødsand 2 offshore substation concrete gravity based)

Post-foundation, a transitional piece is grouted over it adding a flange for connecting and levelling the tower. The transition piece connects the foundation with the tower of the wind turbine. The working platform above the transition is made up of steel which includes ladders, stairs, access routes and power cables.

High Rise Pile Cap (HRPC): The HRPC type is suitable for sea areas with the water depth ranging from 0 to 20 m, applicable to soft soil foundation. It can effectively resist sea water corrosion and is low in cost, reliable and convenient to be constructed. It comprises of a concrete bearing platform higher than the sea level and a group of steel pipe piles at the bottom of the bearing platform, wherein the lower end of the steel pipe pile incline outward slightly.

Suction Bucket: This technology can be visualized as upside-down buckets which are lowered into the marine bed, in order to anchor the offshore structures. The water is pumped out of the bucket, thereby lowering the pressure inside the bucket skirt. The formation of this negative pressure, combined with the weight of the offshore foundation enables the latter to sink deeper into the sea/ocean floor. Suction bucket installation process is can easily reversible, in the event of removal of offshore foundation. This technology is best suited for deep waters and large wind turbines, and it requires essentially little to no seabed preparation.

Best Practices towards Foundation of Offshore Wind Turbines	
Soil Investigation	• Geological, Geophysical and Geotechnical investigations of the building ground • Preliminary soil investigation • Analysis and Execution • Preliminary soil investigation of the soil to prove its suitability
Load bearing stratum	Determination of load bearing bed
Structure of strata	Feasibility of installation
Basic Installation Concept	• Draw up installation concept • Sequence/principle of the installations of wind farm components
Planning/ assessment of necessary ships, barges, etc. (proof of class)	• Identification/Calculation of the required capacities of ships, tugboats, barges of the tugging equipment based on industrial standards
Clearing-up allowed sea state and weather condition with MWS/ certifier	• Plans of the respective steps involve in transport and installation • Consideration of theoretical values for statics, dynamics, acceleration and fatigue of the foundation • Structural design and implementation of requirements for objects to be transported
Registration of components of limited tipping angle	• Checking all the requirements for a limit of heeling/tipping angle • Checking all components for limited acceleration • Identification of appropriate routes for the transport of foundations
Project Engineering	• Planning of transportation concept

Drawing up emergency plans/ designation of responsible persons	• Execution of HAZID/HAZOP • Evaluation of risk assessment • Drawing up emergency plans for transportation and installation stages • Execution of emergency practices
Planning complete: pre-/post- piling	• Selection of piling method and Pre-piling • Check and release of installation procedures • Preparing operating manuals/methods statements • Execution of transport -relevant approvals
Load in/out	• Identification of load in/out method and equipment • Identification of appropriate port/water terminal • Identification of the requirements for the load on the pier areas for handling and storage • Identification of requirements for transport unit • Loading and ballasting • Verification of class documents/ certificates regarding project requirement • Planning and calculation of sea-fastening and grillage
Execution of Offshore transport/ installation	• Planning and calculation of deck structure integrity • Equipment of loading • Identification of load in/out objects • Suitability of the port for jacking • Verification of class documents/ certificates regarding the personnel • Sea-fastening • Stability during construction • Dynamic positioning of crane vessel, tugboat, AHT, supply vessel, jack-up vessel • Bubble curtain to reduce the propagation of hammering sound (relieved foundation systems/monopiles)
Jacking	• Check of trimming/ heeling level for jacking • Jacking down and make the legs stable • Enough distance between the bottom platform edge and maximum wave height • Observance of weather and sea behaviour
Lifting procedure	• Fastening the spreader • Releasing of sea-fastening • Lifting procedure (lifting and depositing)
Setting down the base structure on to the sea bed	• Positioning of foundation on the sea bed (pre-pilling) (under-water) • Positioning of foundation on the sea bed (post-pilling) (under-water) • Alignment of the foundation during installion (under-water) • Alignment of transition piece (monopile) (surface)
Floating installation unit	• Heaving, shock load • Pulling cable into the foundation • Fasting of the cable in the foundation • Connection to wind turbine
Foundations on seabed	• Driving in of piles • Verification of weather conditions
Grouting monopiles; transition piece and pile; Relieved structure	• Selection of grouting material • Use and manipulation of grouting material • Use of grouting equipment • Examine and release grouted structure • Verticality of wind turbine
Admitted scouring	• Installation of scour protection • Integrity of scour protection

For more information, refer the following informative links/material:

1. International guidelines on the risk management of offshore wind farms (https://vds.de/fileadmin/vds_publikationen/vds_3549en_web.pdf)

2. Paper on “Offshore wind turbine foundations- The COWI experience" by Jorn H. Thomsen, Torben Forsbeg (from COWI A/s) and Robert Bittner, P.E. Ben C., Gerwick (Inc. San Francisco, USA) published in June 10-15, 2007. (http://bittner-shen.com/publication/Offshore_Renewable_Energy/Offshore_Wind_Turbine_Foundations_The_COWI_Experience.pdf)

3. Article on “Selection, Design and Construction of Offshore Wind Turbine Foundations” by Sanjeev Malhotra (from Parsons Brinckerhoff, Inc. United States of America) (http://cdn.intechopen.com/pdfs/14804/InTech-Selection_design_and_construction_of_offshore_wind_turbine_foundations.pdf)

4. Informative portal on Offshore wind support structure by 4C Offshore. (http://www.4coffshore.com/windfarms/support-structures-for-offshore-wind-turbines-aid3.html)

5. Information on Offshore Support Structures by European Wind Energy Association. (http://www.wind-energy-the-facts.org/offshore-support-structures.html)

Updated on: **March 2017**

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