Offshore wind projects for the Indian Coast – Experiences and challenges for its realization

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Offshore wind energy is gaining significance around the world as the most suitable source of renewable energy. India, blessed with 7500 km of coastline has already announced the offshore wind energy policy based on feasibility studies for offshore wind potential. National Institute of Wind Energy (NIWE) and M/s Suzlon Energy Limited have installed first LiDAR-based offshore measurement platform with the technical expertise of the National Institute of Ocean Technology (NIOT), MoES in the Gulf of Khambhat and the Gulf of Kachchh. This article illustrates the analysis, design methodology and various innovative strategies involved in the installation of LiDAR-based measurement platforms.

Keywords: Challenges, installation, LiDAR platform, offshore wind energy.

Introduction

THE energy demand has increased substantially world-wide due to incessant escalation in population, extreme usage of fossil fuels and its associated global warming effects due to CO_2 emissions, etc. Many developed and developing economies are exploring feasible options in harnessing various renewable energy sources such as offshore wind, solar power, ocean energy, biomass, geothermal, etc. Offshore wind is one of the most promising sources of renewable energy, not only because of strong and consistent winds, reduced noise pollution, lesser visual intrusions but also in its potential to mitigate climate change, increase energy security and stimulate global economy.

Design of LiDAR platforms

For developing an offshore wind project, a well-designed multi-year wind measurement campaign is essential to validate the identified potential sites mentioned above. *In-situ* measurement should provide 10 min average wind speed and direction at different hub-heights for dependable analysis to attract huge investments. The Ministry of New and Renewable Energy–National Institute of Wind Energy (MNRE–NIWE) installed the LiDAR platform in the Gulf of Khambhat during April 2017 with the technical support of the National Institute of Ocean Technology (NIOT), MoES for design and installation of substructure to support the LiDAR platform. The LiDAR/Met mast that has been set up is in compliance with IEC (International Electrotechnical Commission) standard or equivalent industry standard. Another LiDAR platform has also been installed in the Gulf of Kachchh during October 2017 by M/s Suzlon with the technical support of NIOT.

The offshore platform was designed based on Limit State Method of approach by finite element modelling software. The platform is supported by a monopile of about 1.2 m diameter with 25 mm thickness embedded 15 m into soil. Analysis of the monopile was carried out using finite element modelling software Structural Analysis Computer System (SACS) and structural design based on American Petroleum Institute Recommended Practice (API RP 2A). Wave, wind and currents loads are applied for the super structure. The sub-structure pile soil interaction is modelled based on nonlinear springs according to API RP 2A.

Wind speed of 12 m/s during operational condition and 50 m/s during extreme cyclonic condition obtained from Indian Standards IS 875 Part III was considered for structural design. The wave data extracted from the wave Atlas in the Gulf of Khambhat region, shows a significant wave height of about 2 m in the region. The predominant direction of wave is 225°. The maximum current speed observed in this region is 1.53 m/s during spring and minimum of 0.1 m/s during neap with an average of 0.7 m/s. The currents in this region are dominated by tide and are predominantly bi-directional. The tidal variation in this region is 4 m. The design and analysis of sub-structure is complicated as it experiences extreme conditions of wave, current and wind loads simultaneously. Hence, the joint probability analysis for wave and current has been carried out.

Joint probability analysis for wave and current

The design wave and current values are traditionally derived by fitting a standard distribution to the collected data and checked for the goodness of fit as validation.

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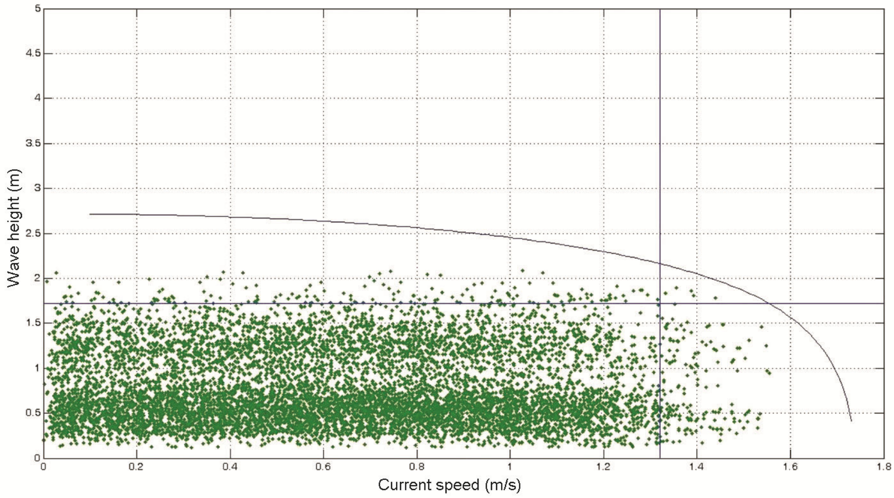

Figure 1. Joint probability for current and wave height.

Table 1. Environmental parameter combination

Wave height (m)	Current speed (m/s)
1	1.55
2	1.50
3	1.42
4	1.20
5	0.37

This standard distribution will be used to get the wind and wave values for a given return period. For example, if the structure is being designed for a return period of 50 years, the 50-year wave height and the 50-year current velocity data will be fit to the standard distribution and the design values will be determined independently and the structure will be designed for the combined occurrence of these two values. This methodology may make the design conservative as it does not take into account the probability of these two events occurring simultaneously, i.e. at the same instant in time[1]. The dependence (or independence) between the two variables in question (wave height and current speed) can be brought out by performing a joint probability analysis which can correct some of the handicaps imposed by the traditional method.

Joint probability (P) refers to the probability of two variables occurring at the same time. The joint probability is given by the expression[2]

$$P = \int_x^\infty \int_y^\infty f(X, Y)\mathrm{d}y\mathrm{d}x,$$

where $f(X, Y)$ is the joint probability distribution, derived using the two standard distributions for wave height and current velocity. In this analysis, for any return period, one could get a curve which will give all possible combinations of the two variables considered.

The probability density functions (PDFs) for the variables concerned (wave height and current velocity) were derived using the simultaneously collected data for a sufficient duration in this analysis[1]. The PDFs were then compared with different standard distributions like Log-normal Distribution, 2-Parameter Weibull Distribution, 3-Parameter Weibull Distribution, Gumbel Max (Maximum Extreme Value Type-1) Distribution, Generalized Extreme Value (GEV) Distribution, Generalized Pareto Distribution, etc. The goodness-of-fit for each standard distribution with the PDFs is then checked using different tests like Chi-square test, Kolmogorov–Smirnov test, Anderson–Darling test and Quantile–Quantile plots. From the goodness-of-fit tests, it was found that GEV distribution fits the best for both wave height and current velocity data. A return period of two years is considered in this study and different combinations of wave height and current speed are obtained from the joint probability distribution curve shown in Figure 1. Different combinations were considered for the analysis as given in Table 1 and the design is governed by the extreme case.

Transportation and installation analysis

Suitable weather window is based on the environmental conditions derived from secondary data. Based on weather window, an installation sequence has been arrived. The Monopile is transported from the fabrication yard in Mumbai and towed to the site in vertical position. Hence, by transporting the structure in vertical position to the site the installation has reduced the cost significantly. The Jack-up barge is modelled in Integrated Naval Architecture Software, MAXSURF and simulations were carried out for the transportation. Response Amplitude Operators (RAOs) of the vessel are found from uncoupled heave, pitch and roll equations of motion. The RAO of

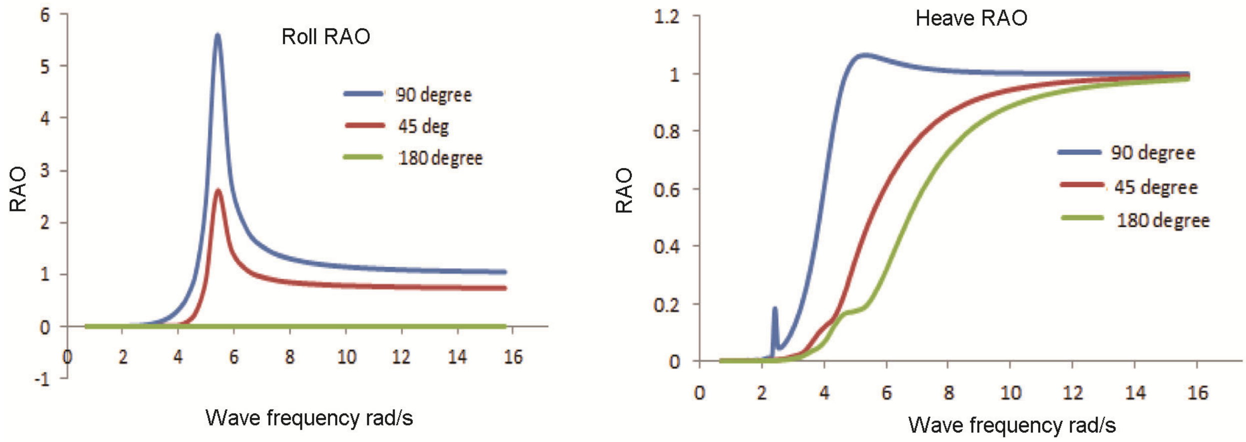

Figure 2. Roll and heave RAO of the vessel.

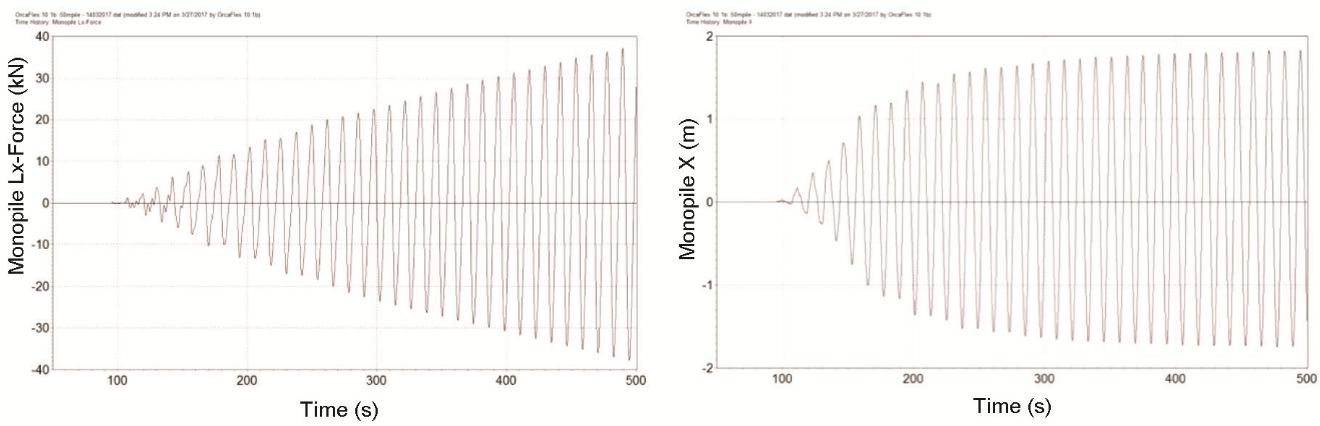

Figure 3. Lateral force and motion on the monopile (extreme event H_s = 3 m and T_p = 12 s).

the vessel is studied for various wave headings such 45°, 90° and 180°. The RAOs are shown in Figure 2. Roll motion experiences peak at 90° heading of the wave and follows the general bell-shaped pattern. Heave amplitude follows the same pattern as that of the wave amplitude. It is found that the peaks of the RAOs are far away from natural wave periods.

Installation of monopile in high tidal and current region is challenging with currently available infrastructure. Hence, lowering analysis of monopile has been carried out to understand the behaviour of the structure. Modelling and lowering analysis of monopile has been carried out using commercial finite element software package, ORCAFLEX used for global static and dynamic analysis and gives options for modelling of vessels, different structures, and connection elements. The results are shown in Figures 3 and 4. Based on these results, a hydraulic gripper to avoid the lateral response of monopile was recommended during the installation in site[3,4].

Summary and conclusions

Two offshore wind data collection platforms were successfully installed in Gulf regions along with site-specific design and analyses. The design was based on inputs from field data and return period analysis using joint probability approach. Finite element tools were used for analysis and design of structure. These two systems are collecting data continuously since their inception in 2017. Accuracy in the data collected in potential sites would pave way for noble bankable wind data. Thus the most significant initial key strategies to be followed towards the development of offshore wind have been achieved. This step would lead the country towards establishing offshore wind energy.

Suitable weather window, based on the environmental conditions has been derived from secondary data. Based on weather window, an installation analysis was carried out including the lowering of monopile in high tidal environment and recommended to utilize the hydraulic

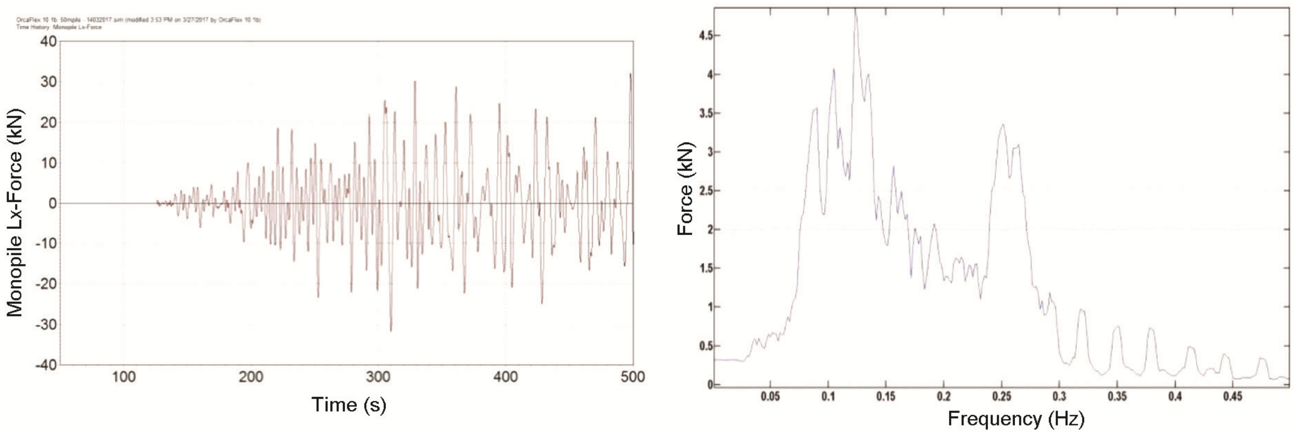

Figure 4. Lateral force on the monopile and FFT (irregular wave H_s = 1.5 m and T_p = 7 s).

gripper to avoid the lateral displacements while lowering the structure. The monopile was transported in vertical position to avoid the usage of expensive vessels from the fabrication yard in Mumbai and towed to the site in Gulf region and successfully installed with available marine spread. The design and analysis of sub-structure is complicated as it experiences extreme conditions of wave, current and wind loads simultaneously.

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