State of the art of Floating Offshore Wind Energy

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1 Introduction

The total installed offshore wind capacity in Europe reached 18.5 GW in 2018, the majority of which is installed in the relatively shallow waters of the North Sea, Irish Sea and Baltic Sea, allowing for bottom-fixed monopile installations. However, available shallow waters are becoming increasingly utilized and about 80% of Europe's offshore wind resource is available in sea areas with water depths over 50 m [1].

Installing Floating Offshore Wind Turbines (FOWT) becomes an economically viable alternative to bottom-fixed wind turbines in water depths over 50 m. As a result, the development of FOWTs has accelerated in recent years, resulting in the first grid-connected commercial floating wind farm off the East Coast of Scotland in 2017.

2 State of the art

There have been numerous designs of FOWTs to date, which can all be classified according the floating support structure for the turbine. Three types of platform have emerged as the dominant designs: the spar, semi-submersible and Tension Leg Platform (TLP). Initially developed for the oil & gas industry, these platform designs have been adapted to support wind turbines and employ different strategies for their stability. The spar relies mainly on large draft and large mass of ballast for stability. Good examples of installed spar FOWTs are Hywind (Equinor) and Hamakaze (Fukushima consortium). The semi-submersible relies mainly on its large buoyancy volume for stability. Good examples of installed semi-sub FOWTs are WindFloat (Principle Power), Mirai (Fukushima consortium) and Floatgen (Ideol). The TLP relies mainly on the constant tension of the mooring tendons for stability, allowing for a smaller platform compared to the spar and semi-sub. The world's first installed FOWT prototype, Blue H, was a TLP.

Figure 1. The three main platform types

The choice of platform type used for FOWTs depends largely on site-specific conditions.

There are currently several interesting FOWT designs under development, among them; Eolink, a semi-sub with a single point mooring system to negate a turbine yawing system and four small towers in a pyramid configuration to support the nacelle and rotor; TELWIND, a spar type FOWT which consists of a floater with a pendulum ballast tank suspended by tendons to the floater. This allows for transport from relative shallow water ports to the installation site; SBM Floater, a hybrid between the semi-sub and TLP.

3 Outlook for Floating Wind Energy

Hywind Scotland Pilot Park is currently the only grid-connected floating wind farm in the world. However, with the WindFloat Atlantic (Portugal) and Kincardine (Scotland) farms under construction and several planned floating farms for the coming years, including four farms with a combined total of 100 MW planned for 2021 in France alone, the outlook for floating wind energy is bright. Costs for floating wind energy are expected to decrease to €40-60/MWh by 2030 and the cumulative installed capacity is expected to reach around 4 GW in 2030 [2].

4 Scale model testing

As there are currently no datasets publicly available on the behavior of full-scale FOWT prototypes in real offshore conditions, scale model testing is a very important stage in the development of FOWT designs. To validate their numerical models, designers rely mostly on scale model testing in laboratory basins. It is therefore essential to minimize the uncertainty of said tests. However, the coupled aero/hydrodynamics of FOWTs cause a scaling conflict due to working in two fluid domains: water and air. The gravity dominated hydrodynamics are Froude scaled, whereas the flow dominated aerodynamics are Reynolds scaled. The two main techniques to overcome the scaling conflict are: Froude scaled rotors with low-Reynolds airfoils and above basin generated wind, or hybrid testing.

In hybrid testing the above basin generated wind is replaced by a real-time numerical wind field. The Froude scaled aerodynamic forces are emulated by an actuator on the scale model, without having to rely on a correct Reynolds number for the turbine blades [3,4].

Bibliography

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