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Prospects of Floating Wind Energy

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Floating wind turbines are complex dynamic systems. The dynamics and design of such systems pose interesting engineering and scientific challenges. Although there already exist some informative and valuable reviews of this topic, there have been many additional and important studies in more recent years. This topical paper reviews the main developments and research avenues currently under way, focusing on recent research literature. It addresses specific challenges of floating wind turbines and introduces key issues focused on the floating platform. In addition, recommendations for further research are introduced.

INTRODUCTION

The concept of floating wind turbines is as old as the idea of offshore wind turbines itself. In order to use the vast offshore wind resources, Heronemus proposed floating wind turbines already in 1972 (Heronemus, 1972). However, it took approximately 20 years to even produce electricity with fixed offshore wind turbines: in 1991, the offshore wind park "Vindeby" was commissioned, featuring eleven turbines with monopile substructures. Only two years after that, the FLOAT project was accomplished (cf. Tong, 1998). FLOAT proposed to mount a three-bladed horizontal-axis wind turbine on a spar-type floater with catenary mooring lines and also realized a model test with this concept. Since then, many different concepts for floating wind turbines have been proposed and investigated. This led to the world's first full-scale floating wind turbine, the Hywind prototype, which was installed in 2009 (Skaare et al., 2015). Since then, more concepts have been proposed, more prototypes have been realized, and much more research has been done with respect to floating wind turbines.

The reasons for pursuing floating wind energy as opposed to continuing to work with fixed-bottom offshore wind turbines are manifold. Floating wind turbines can be installed with less noise emission compared to fixed-bottom wind turbines, as piling is typically not necessary. Furthermore, depending on the floating concept and location, the system can be assembled from the quay and/or in sheltered waters and then towed to the location with standard offshore vessels (in contrast to specialized and expensive installation vessels that are used for fixed-bottom offshore wind turbines). The time needed for costly marine operations, such as installation of the turbines, is thereby significantly reduced.

However, the most important argument for floating wind turbines is their independence from water depth compared to fixed-bottom substructures. The feasibility of the latter has an economic limit that strongly depends on the water depth. This limit is softer for floating wind turbines. Hence, floating wind energy is especially interesting when sites for fixed-bottom wind turbines become scarce (e.g., in the UK) or when mainly deepwater sites are available (e.g., in Japan, Norway, or the USA).

Offshore wind turbines are getting bigger and are being installed in deeper waters (Arapogianni et al., 2013). This results in a huge interest from both the industry and research community to bring floating offshore wind turbines (FOWTs) into the market at a reasonable cost of energy. Henderson and Witcher (2010) and Wang et al. (2010) previously reviewed the state of the art of floating wind energy. However, since 2010 the number of publications dealing with floating wind energy has grown exceptionally (James and Costa Ros, 2015). The recent review by Tande et al. (2015) focuses more on a general overview of existing prototypes than on details and research aspects. This motivated the need for a more recent, in-depth review of the research on floating wind energy. In Strach-Sonsalla and Muskulus (2016), we presented and discussed the current state of the art in terms of design and dynamics of floating wind turbines, taking into account the latest literature. Readers should consult that paper for more information on the scientific background and additional references. Parts of this paper have been inspired by the recently published long-term research strategy of the European Academy of Wind Energy (van Kuik et al., 2016). In the present paper the focus is on the current issues and challenges for floating wind turbines, and more detailed recommendations for future work and research are given.

SPECIFIC CHALLENGES

The design of floating wind turbines is complicated by a number of challenging issues that are illustrated in the following. Some of these issues are similar to the situation for fixed-bottom offshore wind turbines, as discussed by Muskulus and Schafhirt (2014), whereas some are specific to floating wind turbines.

Highly Dynamic and Complex Stochastic Environment

Wind and waves are the primary source of loading for not only floating wind turbines, but offshore wind turbines in general. Detailed measurement campaigns are necessary to predict the wind and wave climate, which are of stochastic nature. When analyzing a floating wind turbine, i.e., simulating it, it is important

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