ABSTRACT

This work presents a comprehensive dynamic-response analysis of six offshore floating wind turbine concepts. Each of the six models contained the same 5-megawatt (MW) turbine. The platforms modeled included: a barge, a semisubmersible, two tension-leg platforms (TLP), and a spar buoy at two different depths. The performance of these models was compared to that of a base model with a turbine supported by a fixed land-based tower. Performance was evaluated via a comprehensive loads and stability analysis adhering to the procedures of the International Electrotechnical Commission (IEC) 61400-3 offshore wind turbine design standard. The loads in the turbine supported by the barge are the highest found for the floating concepts. The differences in the loads between the TLP, the semisubmersible, and the spar buoy are not significant, except for the loads in the tower, which are greater in the spar and semisubmersible systems. The results of this analysis will help resolve the fundamental design trade-offs between the floating-system concepts.

INTRODUCTION

Currently, most offshore wind turbines are installed in shallow water on bottom-mounted substructures. These substructures include gravity bases and monopiles used in water to about 30-meter (m) depth and space-frames—such as tripods and lattice frames (e.g., “jackets”)—used in water to about 50-m depth. In contrast, harnessing much of the vast offshore wind resource potential of the USA, China, Japan, Norway, and many other countries requires installations to be located in deeper water. At some depth, floating support platforms will be the most economical type of support structure to use.

Numerous floating support-platform configurations are possible for use with offshore wind turbines, particularly when considering the variety of mooring systems, tanks, and ballast options used in the offshore oil and gas (O&G) industry. The platforms, however, can be classified in terms of how they achieve basic static stability in pitch and roll. The three primary concepts are: the TLP, which maintains stability primarily through the mooring system and excess buoyancy; the spar buoy, which maintains stability from a deep draft combined with ballast; and the barge, which uses a large waterplane area and shallow draft to maintain stability. Hybrid systems use a combination of these three stability methods. For instance, a semisubmersible is a hybrid concept that relies on large waterplane area as well as a fairly deep draft and ballasting to maintain stability.

To help understand the fundamental design trade-offs between the different concepts, a quantitative comparison is made between the dynamic responses of a variety of floating wind systems. This paper examines six floating systems, and compares their performance to a wind turbine on land. Three of the floating systems have been examined previously in Jonkman and Matha 2010, and the other three are generic systems created for a demonstration project led by the DeepCwind consortium (www.deepcwind.org) based out of the University of Maine (see DeepCwind). The original three concepts include the MIT/NREL TLP, the OC3-Hywind Spar, and the ITI Energy Barge, which incorporates a concept from each of the three primary stability categories. The three new concepts created for the University of Maine project include the UMaine TLP, the UMaine-Hywind Spar, and the UMaine semisubmersible. Both the TLP and semisubmersible are very different from the original MIT/NREL TLP and barge, but the spar remained the same. The only difference between the UMaine-Hywind Spar and the OC3-Hywind Spar is the water depth in which the design was analyzed. All University of Maine designs are analyzed at a water depth of 200 m, which represents the depth of a test site for floating wind turbines off the coast of Maine.

OVERVIEW OF THE ANALYSIS APPROACH

The overall design and analysis process applied in this project consists of the following steps:

1. Use the same wind turbine specifications—including specifications for the rotor, nacelle, tower, and controller—for each system. (Minor modifications to the specifications are needed in some cases; see Step 2.) Likewise, use the same environmental conditions for each analysis—including meteorological (wind) and oceanographic (wave), or “metocean,” parameters. Using the same