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Important Measurement Parameters for Determining Loading and Energy Production on Offshore Wind Turbines

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Abstract

This paper identifies the environmental parameters that need to be defined when determining loadings on offshore wind turbine structures imposed by the wind, waves, and currents. It also identifies important parameters for predicting a wind facility's long-term energy production. This paper also describes an offshore field research program initiated near the coasts of New York and New Jersey in 2005 to measure and model the meteorological and wave environment specifically for wind energy development purposes. The research aims to provide wind system designers with new datasets and tools to obtain site-specific design criteria and loading data necessary to cost-effectively engineer and optimize offshore wind facilities in the Atlantic region of the United States.

Introduction

As planning of two offshore wind energy facilities advances in the northeastern United States, interest in offshore wind development is spreading throughout much of the rest of coastal America, including the Gulf Coast and Great Lakes regions. While the potential for new wind-based generating capacity in coastal waters is great, the technical know-how to engineer offshore wind facilities for long-term durability and economic viability is in its formative stages. Hydrodynamic and atmospheric forces must be defined in terms of their magnitude, frequency, and variability in time and space.

This paper identifies the parameters that need to be defined when determining loadings on offshore wind turbine structures—foundations, towers, and blades. It also identifies important parameters for predicting a wind facility's long-term energy production. Both types of data must be defined to advance engineering design activities and attract the financing necessary to eventually support the deployment of commercial offshore wind energy facilities. The role of simulation models to predict loads and forces are addressed.

This paper also describes an offshore field research program initiated in mid-2005 to measure and model the meteorological and wave environment in the Atlantic specifically for wind energy development purposes. The research results are aimed at providing wind system designers with new datasets and tools to obtain site-specific design criteria and loading data necessary to cost-effectively engineer and optimize offshore wind facilities in the Atlantic region.

Data Parameters

The design and control elements of an offshore wind system are inclusive of the foundation, tower, drive train, rotor, and balance of plant components. Environmental conditions expressed in terms of means, frequencies, standard deviations, and extremes are required to understand and design for the wind and wave loadings over the expected operating life of the wind plant. The availability of this information will allow designers to more appropriately match a turbine or foundation designed for a particular load regime with the conditions that are expected at a particular site.

Manufacturers of offshore wind systems have defined relevant environmental design parameters needed for site-specific applications, including:

- Hub height wind speed and direction (mean speed, frequency distribution by direction sector, wind rose, etc.)
- U, V, W wind components
- Extreme gusts (3-s, 5-s, 1-min, 10-min) for 50-yr return period
- Annual operating gust amplitude
- Wind shear exponent and structure across rotor plane
- Turbulence (ambient and wake induced) (magnitude and integral length scales)
- Significant wave heights for multiple return periods
- Storm surge levels
- Currents (tidal, storm surge)

These parameters will be critical in determining the appropriate structural loading on the turbine as required for Germanischer Lloyd (GL) certification, and to satisfy the