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Electrical Collection and Transmission Systems for Offshore Wind Power

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Abstract

The electrical systems needed for offshore wind farms to collect power from wind turbines—and transmit it to shore—will be a significant cost element of these systems. This paper describes the development of a simplified model of the cost and performance of such systems. The performance prediction accounts for losses as a function of the power produced in the wind farm and the length and size of the cables. The cost prediction is flexibly formulated so wind farm configurations can be evaluated by parameters such as the number of wind turbines, wind turbine size, turbine array configuration and spacing, and distance from shore. The collection system—the medium-voltage electrical grid within the wind farm, and the transmission system—the high-voltage electrical connection to an on-shore transmission line—are treated independently in the model. Data sources for the model and limitations of the data are discussed, and comparison is made to costs reported by others. The choice of transmission system technology is also addressed. This electrical system model is intended for integration into a more comprehensive model of offshore wind farm design, cost, and performance that will be used for parametric studies and optimization of wind farm configurations. Because some concepts for future offshore wind installations in deep water use floating platforms, this paper briefly discusses the application of submarine cable technology to nonfixed termination points, a departure from current practice.

Introduction

The National Wind Technology Center (NWTC) of the National Renewable Energy Laboratory (NREL) in Golden, Colorado, has undertaken a series of concept studies to evaluate the cost and performance of offshore wind farms. The product of these studies will be a comprehensive model of offshore wind farm design, cost, and performance suitable for parametric studies and optimization of wind farm configurations. The overall goal of this effort is to help identify technology pathways for offshore wind energy development and deployment in the United States. Offshore wind farms present an attractive option because they allow for larger wind turbines that operate in higher wind resources than land-based [1,2]. Offshore installations are also more expensive, so an understanding of their performance, cost, and optimal configurations is needed.

This paper is an overview of one of these concept studies. It focuses on the power losses in wind farm electrical power collection and transmission systems, as well as the costs of the system components and their installation. A hypothetical system was based loosely on the Horns Rev offshore wind farm in Denmark. Inquiries were made with manufacturers about electrical and cost data on the required components, which were then compiled in a spreadsheet model. The performance prediction accounts for losses as a function of power output of the wind farm and length and size of the cables. The cost prediction is flexibly formulated so wind farm configurations can be evaluated by parameters such as the number of wind turbines, wind turbine size, turbine array configuration and spacing, and distance from shore.

Electrical System Overview

The electrical system for an offshore wind farm consists of a medium-voltage electrical collection grid within the wind farm and a high-voltage electrical transmission system to deliver the power to an onshore transmission line.

Collection System

The collection grid begins with transformers at each wind turbine, usually in the base of the tower, to step up from the generation voltage, typically 690 volts (V), to a medium voltage of typically 25–40 kilovolts (kV). This voltage range seems to be preferred because standardized equipment is available at competitive prices and because higher voltage transformers would be too big to fit readily into the tower cross sections. A grid of medium-voltage submarine cables, typically buried 1–2 meters (m) deep in the seabed, is used to connect the wind turbines to an offshore substation.

Transmission System

The transmission system begins at the offshore substation, which steps up the voltage to a transmission voltage of 130–150 kV, the highest voltages in use today for AC submarine cables. This higher voltage allows a much smaller diameter