Chapter 5
Dynamic Analysis of Offshore Wind Turbine Structures

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ABSTRACT
Wind turbines are slender flexible structures susceptible to strong wind fluctuations. The flexible wind turbine structure, when subjected to strong dynamic forces, it leads to an ideal condition for induced vibrations and resonance problems. Hence studying the dynamic response of these critical structures using the computational and experimental procedures becomes of utmost importance. This chapter reviews the theories used for the dynamic analysis of a modern day offshore wind turbine structure and applies these theories in analyzing realistic situations for offshore turbines under wave and wind action. The first half of the chapter gives a broad overview on the concepts of structural dynamics of wind turbine structures with illustrative examples that will enable the user to understand the methodology used to analyze these structures. The latter half of the chapter deals with the computational aspect of the analysis and focuses on the use of finite element software ANSYS 14 to model these critical structures.

INTRODUCTION

History of Onshore and Offshore Wind Turbines
The first windmills were constructed in Persia in the seventh century for irrigation purposes and for milling grain (Kaul et al., 2007). These old wind turbines were made of wood. The modern construction of windmills started at the time of industrial revolution. With the progress of industrial revolution, the industrialization sparked the development of larger windmills to generate electricity. The first electricity generating wind turbine was developed by Poul la Cour (2000). Later, larger and heavily engineered wind turbines were designed by Charles F. Brush from Cleveland, Ohio who designed a larger and heavily engineered wind turbine in 1888. The Brush wind turbine had a rotor of 17 m (56 feet) in diameter and it was mounted on an 18 m high (60 feet) tower.

DOI: 10.4018/978-1-5225-0588-4.ch005
Although gigantic by today’s standards, the power rating of the turbine was only 12 kilowatt (kW); it rotated slowly as it had 144 blades. In the late 1930’s, a megawatt-scale wind turbine generator was first time developed in the United States of America (USA) which made use of the latest technology. In 1941, a 1.25 megawatt (MW) Smith-Putnam wind turbine (Robert, 1996) was built in USA using the above mentioned turbine generator. Back in 1941 it was the largest wind turbine ever built and it kept its leading position for 40 years. In 1991, the first offshore wind farm was installed in Denmark. The wind farm consisted of eleven, 450 kW turbines.

At the dawn of 21st century, fossil fuel was still comparatively cheap. However, rising concerns over energy security, global warming, and eventual fossil fuel depletion led to development of interest in all available forms of renewable energy.

By 2014, over 240,000 commercial-sized wind turbines were operating in the world, producing 4% of the world’s electricity. Total installed capacity exceeded 336 gigawatt (GW) in 2014 with China, the U.S., Germany, Spain and Italy leading in installations as reported by Anon, (1890), Global Wind Report (2014), American Bureau of Shipping (2014), American Petroleum Institute (2014), British Standard Europaische Norm. (2004). By 2015, the largest wind turbine of 8 MW capacity by Vestas named V164 was ready for offshore use (Global Wind Report, 2014).

**Components of a Typical Wind Turbine**

A wind turbine typically comprises of three blades connected by a rigid hub. The hub is attached to a nacelle containing the mechanical and electrical components of the turbine. The blade-hub-nacelle assembly is supported by a tower as shown in Figure 2. The nacelle houses some of the important electrical components used for wind energy conversion like rotor and shaft and is mounted on top of the tower. The electric current is then distributed by a transformer to the grid with the help of transmission lines.

*Figure 1. (a) Charles Brush’s windmill of 1888, used for generating (b) 1.250 MW Smith-Putnam wind turbine
Source: Anderson (2003).*

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