Challenges in Simulation of Aerodynamics, Hydrodynamics, and Mooring-Line Dynamics of Floating Offshore Wind Turbines

Denis Matha, Markus Schlipf
Endowed Chair of Wind Energy, Universität Stuttgart
Stuttgart, Germany

Andrew Cordle
Garrad Hassan and Partners Ltd.
Bristol, United Kingdom

Ricardo Pereira
Germanischer Lloyd Industrial Services, Renewables Certification
Hamburg, Germany

Jason Jonkman
National Renewable Energy Laboratory
Golden, Colorado, USA

ABSTRACT

This paper presents the current major modeling challenges for floating offshore wind turbine design tools. It also describes aerodynamic and hydrodynamic effects due to rotor and platform motions and usage of non-slender support structures. The applicability of advanced potential flow and computational fluid dynamics–based aerodynamic and hydrodynamic simulation methods to represent these effects—exceeding state-of-the-art design tool capabilities—is analyzed and the results are presented. Different techniques for the representation of mooring-line dynamics, including quasi-static, finite element, and multibody methods, and their impact on global system loads are investigated. Conclusions are drawn about the importance of the relevant effects, strengths and weaknesses of the different methods are discussed, and development needs of future tools are described.

KEY WORDS: Offshore; floating wind turbine; integrated design tools; mooring system; aerodynamics; hydrodynamics; potential flow; computational fluid dynamics; CFD; multibody simulation; MBS.

INTRODUCTION

Combined aerodynamic, hydrodynamic, and mooring-system dynamic effects on floating offshore wind turbines (FOWT) create unique operating and failure design conditions which have not yet been studied in great detail. The large rotor and platform motions and the use of non-slender support structures potentially render state-of-the-art techniques applied for modeling fixed-bottom offshore wind turbines—for example the blade element momentum (BEM) method for rotor aerodynamics and Morison’s equation for hydrodynamics—insufficient for accurately describing the dynamics of floating wind turbines.

Addressing these limitations and effectively designing and analyzing wind turbines on offshore floating support structures requires advanced modeling methods and techniques.

Dedicated hydrodynamic and mooring-system codes and techniques developed for the oil and gas industry for analysis of ships and oil platforms, as well as advanced aerodynamic methods used in the aircraft and helicopter industry, which are capable of addressing most effects relevant for FOWTs are not readily applicable for integrated FOWT simulations. The specific coupled aero-servo-hydro-elastic dynamics of FOWT and the requirements of the International Electrotechnical Commission (IEC) standard and certification guidelines (2009) to run large numbers of design load simulations must be considered when analyzing the application of existing and novel methodologies.

In sum, this paper describes the important physical effects unique for FOWTs in theory and the current major modeling challenges in FOWT design codes. It introduces techniques and methodologies to overcome the limitations of current integrated simulation tools, discusses their applicability for the simulation and analysis of FOWTs, and presents first indicative results of new approaches, including computational fluid dynamics (CFD) aerodynamic models and multibody system (MBS) mooring-line representations. This work also draws conclusions about the importance of the relevant effects, strengths, and weaknesses of the different methods and notes the development needed.

AERODYNAMICS

Aerodynamic Effects on Floating Wind Turbines

All of the design codes currently capable of performing integrated modeling of floating wind turbines (Cordle and Jonkman, 2011) use the