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ScienceDirect

Energy Procedia 80 (2015) 312 – 320

Energy Procedia

12th Deep Sea Offshore Wind R&D Conference, EERA DeepWind'2015

Effect of Turbulence Intensity on the Performance of an Offshore Vertical Axis Wind Turbine

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Abstract

Offshore wind energy is one of the most competitive renewable energy resources available to us, which until now been under-exploited. Most of the problems associated with wind farm installation like land acquisition, low wind conditions and its visual impact can be eliminated to large extent by going offshore. In fact it is expected that by the year 2020, 40GW of offshore wind power capacity will be in operation. In an offshore context the wind turbine design methodologies have to address new challenges. For optimal performance the turbine needs to be huge in size and for horizontal axis wind turbines (HAWT) the diameter has already reached a size of 200m. Till now little attention has been paid to vertical axis offshore wind turbines. However, within the NOWITECH project new concepts for vertical axis turbine have been proposed and it might not take a long time before such turbines may become an realistic alternative for use offshore. The current work characterizes variable turbulence intensity flow field around a rotating vertical axis wind turbine (VAWT) in an offshore context. Complete three dimensional numerical transient simulations are performed accounting for the variation of multiple turbulence intensity levels associated with the oncoming wind. Usually offshore winds are highly turbulent in nature partially because of the rapid changes in wind directions along with the sea-air interaction. The results from the study indicate that due to the increase in the turbulence intensity level of 5% to 25% the performance of wind turbine decreases by almost 23% to 42% compared to no turbulence in the incoming wind field.

Peer-review under responsibility of SINTEF Energi AS

Keywords: Wind Energy, Vertical Axis Wind Turbine, Computational Fluid Dynamics, Variable Turbulence Intensity

1. Introduction

With the increase in the demand for more sustainable global energy, wind energy is emerging as one of the most economical alternative in comparison to the rest of renewable energy resources. At first, wind energy installation gained attention in an onshore context only. Large horizontal axis wind turbines (HAWTs) has been designed and integrated to develop wind farms able to produce MW's of energy. However due to low wind speeds, small number of potential wind sites and visual impacts on land, offshore wind industry now experience rapid growth. Recently, the installation of huge wind power plants in the North Sea and the Baltic Sea opens possibilities for the power

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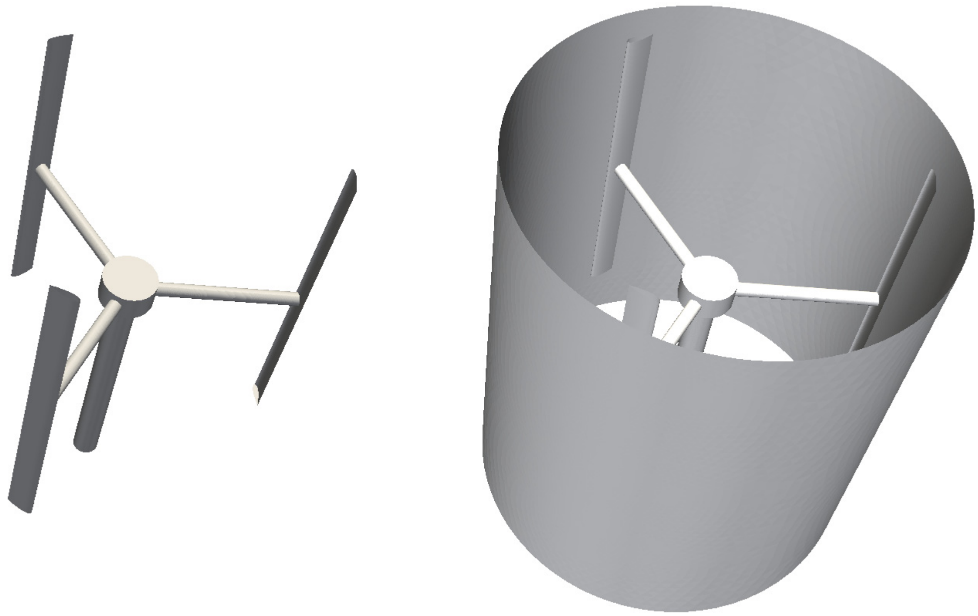
Peer-review under responsibility of SINTEF Energi AS
doi:10.1016/j.egypro.2015.11.435



(a) H-type VAWT (Diameter = 2.5m, Chord = 0.2m)

(b) Sliding zone surrounding VAWT (Diameter = 3m)

Fig. 1: **H-type VAWT**: Overview of H-type vertical axis wind turbine (VAWT)

production and development of offshore wind turbines. Presently, the cost associated with the installation of offshore wind turbines is higher than installations onshore, and this is considered to be an obstacle for increased investment in offshore wind energy. One important step to overcome this is to design more reliable and efficient turbines for offshore use. Recently, new turbine designs are being introduced to address this issue. Along with horizontal axis wind turbines, new design of vertical axis wind turbine (VAWT) have also emerged, see [1]. One such type of wind turbine that recently has gained popularity is the H-type VAWT, see e.g. [2] and [3]. It has straight blades that can harvest the energy from the wind regardless of the wind direction. This unique feature reduces major costs associated with the traditional HAWT that needs to be aligned with the incoming wind. The H-type VAWT is also considered to be ideal for installations where wind conditions are not consistent i.e. turbulent wind conditions.

The overall objective of this study is to investigate how the performance of vertical axis wind turbine (VAWT) is altered with the change in the turbulence intensity of the incoming flow field. The study covers the expected variations of the wind field that offshore wind turbines will be exposed to. Results are presented in time domain to predict the impact on turbine efficiency in terms of overall torque and power coefficients. The idea is to quantify the performance parameters with varying inflow conditions. Variable flows offer multiple challenges in analyzing aerodynamic and structural behavior of wind turbine. Thus, solid understanding of the flow physics is needed to reduce the risks and increase the performance of wind turbines. Moreover, it also help in the fatigue assessment of the support structures to develop new classes of materials which may further improve the offshore wind turbine technology.

The study herein is a continuation of previous related work by the authors in the field of wind energy modeling. See e.g. [4], [5] and [6] for previous work related to VAWTs, whereas the papers [7] and [8] gives an overview of the work on multi scale modeling for both on-shore and offshore wind turbines and wind farms. Finally, we mention here the work on high Reynolds number aerodynamics of wind turbine blades; see [9], and [10].