Renewable Energy 128 (2018) 391–399

Contents lists available at ScienceDirect

Renewable Energy

journal homepage: www.elsevier.com/locate/renene

Technical potential assessment of offshore wind energy over shallow continent shelf along China coast

Bingchuan Nie [a], [b], [**], Jiachun Li [c], [d], [*]

[a] School of Civil Engineering, Beijing Jiaotong University, Beijing 100044, China
[b] Beijing's Key Laboratory of Structural Wind Engineering and Urban Wind Environment, Beijing 100044, China
[c] Key Laboratory for Mechanics in Fluid Solid Coupling System, Institute of Mechanics, Chinese Academy of Sciences, No.15 Beisihuanxi Road, Beijing 100190, China
[d] School of Engineering Science, University of Chinese Academy of Science, Beijing 100049, China

ARTICLE INFO

Article history:
Received 13 November 2017
Received in revised form
2 May 2018
Accepted 23 May 2018
Available online 28 May 2018

Keywords:
Wind energy
Offshore wind farm
Floating wind turbine
GIS
Surface roughness length

ABSTRACT

Offshore wind resource assessment seems to be urgently needed due to the rapid development of offshore wind energy in the coming decades. Technical potential of offshore wind energy over the sea area shallower than 250 m along China coast is investigated. To avoid erroneous estimation of wind power density, a statistical model considering sea state effect is proposed. Long-term CCMP wind field data are examined using that model to reduce uncertainties. Further, influential factors including wind power density, water depth, wind turbine size, wind farm layout and various spatial constraints are analyzed on the GIS platform. Technical potential under different scenarios are presented and discussed. It shows that wind resource at Taiwan Strait is particularly abundant, where wind power density at 70 m height can be above 900 W/m^2. Technical potential is quite sensitive to the size of wind turbine. Taking the layout S1 (8×15 turbines in each farm, 8 rotor diameters apart between wind turbines, 20 km buffer region between neighboring farms) as an example: the total technical potential of the study area is 613 GW for rotor radius 60 m, and that for rotor radius 90 m is 1264 GW; the growth rates of technical potential with rotor radius is 19.3 GW/m roughly. Spatial constraints has significant impact on the region with water depth less than 50 m, where only 48.1% of area is available for developing wind energy and the technical potential there is about 23% of that of the study area.

© 2018 Published by Elsevier Ltd.

1. Introduction

Offshore wind energy experienced a recordable period and exhibits great growth potential in the coming years because of its advantages in larger wind speed, lower wind shear, fewer noise constraints and less land occupation. By the end of 2017, the global cumulative capacity reached 18.81 GW, in which 15.73 GW was newly installed during 2011–2017 according to Global Wind Energy Council (GWEC) [1]. The new intermediate scenario by European Wind Energy Association (EWEA) claimed that 66 GW offshore capacity is expected to be added in EU by 2030, and those of the high/low scenario is 45 GW/98 GW [2]. National Renewable Energy Laboratory (NREL) predicted 38 GW of installed capacity is expected to be commissioned by 2020 in US, which would bring the cumulative installed capacity to 47 GW [3]. Recently, a plan “The Electric Power Development Planning in 13th Five-Year (2016–2020)” was released by the National Energy Administration of China (CNEA), which sets a goal of offshore wind capacity by 2020: 5 GW under commercial operation and 10 GW under construction [4].

Offshore wind resource assessment plays an important role in developing offshore wind energy. It can be usually classified into two scales, i.e. wind farm and regional scales. As for the wind farm scale, the accuracy of prediction of the annual energy production is the overriding concern, which is fluctuated by various uncertainties such as wind measurement, thermal stability of marine boundary layer and climate change. While the regional scale wind resource assessment is aimed to obtain the technical wind energy potential which will be helpful for the future offshore wind energy planning

---

[*] Corresponding author. Key Laboratory for Mechanics in Fluid Solid Coupling System, Institute of Mechanics, Chinese Academy of Sciences, No.15 Beisihuanxi Road, Beijing 100190, China.
[**] Corresponding author. School of Civil Engineering, Beijing Jiaotong University, Beijing 100044, China.
E-mail addresses: bcnie@bjtu.edu.cn (B. Nie), jcli05@imech.ac.cn (J. Li).

https://doi.org/10.1016/j.renene.2018.05.081
0960-1481/© 2018 Published by Elsevier Ltd.

and the development of the offshore wind turbines. In this work, the regional scale wind energy potential over the sea area shallower than 250 m along China coast are investigated.

China's pilot offshore wind farm right nearby the Donghai Bridge was built in 2005 and the cumulative offshore wind capacity has hit 2.79 GW by the end of 2017. Wind energy potential over the coastal and tidal regions of Bohai Sea, Yellow Sea and East China Sea were firstly investigated by China Meteorological Administration (CMA) using the numerical model WERAS/CMA [5]. With the aid of MM5 model, Qin et al. [6] evaluated the offshore wind energy along the China coast at 100 m hub height. Hong et al. [7] investigated available offshore wind energy over the exclusive economic zone (EEZ) of China considering technical, spatial and economic constraints. Li et al. [8] investigated the climatology, variability, and extreme climate of winds over Bohai Sea and Yellow Sea using a regional climate model COSMO-CLM. And they also reviewed the other works related to wind resource over the seas of China before 2016, e.g. Refs. [9–11]. The geographical distribution of wind power density (WPD) over the seas of China has been uncovered preliminary owing to those works. However, the offshore wind energy potential over the seas of China are not complete yet. The major limitations of the previous works are: 1) most of the wind energy potential are at a few low heights which seems to be incompetent for the large-size modern wind turbines; 2) theoretical wind energy potential over China Seas such as 883 GW [12] (water depth 0–50 m, height 10 m), 660 GW [13] (region 10 km offshore, height 10 m) and 2000 GW [5] (water depth 5–25 m, height 50 m) are seldom available even seem to be contradictory; 3) technical wind energy potential have been discussed scarcely.

Three kinds of wind speed data are often used for wind resource assessment. One is from the in-situ measurement platforms such as meteorological masts, weather stations, ships and buoys. However, offshore observation platforms are quite rare due to the high costs of installation and maintenance. Additionally, the in-situ measured wind speed data are always point measurement with low spatial coverage limiting their application in regional scale wind resource assessment. Wind field data from numerical models with high temporal and spatial resolutions have also been using for offshore wind resource assessment. Ulazia et al. [14] estimated the wind energy potential in the Bay of Biscay relied on the mesoscale model WRF with/without 3DVAR data assimilation. They concluded that wind data obtained with data assimilation has better accuracy than that without data assimilation. Mattar [15] estimated the offshore wind energy potential for the central coast of Chile by WRF and wind speed data from in-situ stations and ERA-Interim reanalysis. Amirinia et al. [16] evaluated the wind and wave energy potential over Caspian Sea using the ECMWF wind data in which the QuikSCAT data are assimilated. Other numerical models such as MM5 [17,18], PROTHEUS [19] and COSMO-CLM [8] have also been relied on for offshore wind resource assessment. Ocean surface responds to wind forcing on many wavelengths providing a mechanism for the microwave remote sensing of ocean surface wind from space, which is competent to offshore wind resource assessment as well. Capps et al. [20] evaluated global offshore wind energy potential using 7 years QuikSCAT wind speed data. Hasager et al. [21] mapped the wind resource over Baltic Sea using the data from Advanced SAR on-board Envisat satellite. Gadad et al. [22] investigated the offshore WPD at 10 m and 90 m over Karnataka state in India using Oceansat-2 scatterometer wind data. Those satellite based wind field data have high spatial coverage. And their quality can be highly improved with the help of the aforementioned traditional in-situ measured wind data [23,24]. Since the regional scale wind resource assessment has lower requirement of temporal and spatial resolutions than that of the wind farm scale, it seems that using satellite based wind field data directly rather than numerical products may gain a more accurate estimation of regional offshore wind resource. Because the analysis and reanalysis datasets based on satellite observations are often used as inputs for the numerical models, which means deviations of numerical products come from the numerical model itself and the observations.

As we know, the satellite based wind field data are often adjusted to a common reference height, say 10 m. To obtain an adequate estimation of WPD at hub height of modern wind turbines, say 90 m for 5 MW [25] even 120 m for 10 MW [26], precise vertical extrapolation of wind speed is a key problem to be solved. The logarithmic law and power law are the most commonly used wind profile during extrapolation. As for the logarithmic law wind profile, a constant sea surface length is usually assumed for the study area in literature, say 0.2 mm, e.g. Refs. [7,12,13,22]. In the power law wind profile model, the power index has also been regarded as a constant neglecting the influence of sea state, e.g. Refs. [27,28]. However, sea surface roughness length can vary in several decades due to the evolution of wave height and shape [29]. Inaccurate estimation of sea surface roughness will certainly introduce deviation of wind speed at hub height. Even worse, the deviation will be further enlarged in WPD, which is proportional to cube of wind speed. To estimate the sea surface roughness length considering sea state effect, recently, Amirinia et al. [16,30] used the wave parameters simulated by wave model SWAN. Since the marine boundary layer has been extensively studied with a lot of achievements available, developing a statistical model filling the gap between the present understanding of marine boundary layer and the requirement of regional scale offshore wind resource assessment may be another way out. However, in the authors' knowledge, such a statistical technical wind energy potential model is still blank yet.

In this work, a statistical model considering sea state effect is proposed and discussed for calculating technical potential in Section 2; based on that, influential factors related to developing offshore wind energy such as wind power density, water depth, wind farm layout and various spatial constraints are examined on the GIS platform; regional scale technical potential of offshore wind energy over the sea area shallower than 250 m along China coast under different scenarios are presented in Section 4; finally, Section 5 brings this study to a few conclusions.

2. Technical potential model considering sea state effect

2.1. WPD at reference height

The available wind energy potential per unit area perpendicular to the air flow, i.e. WPD, is expressed as

$$P = \frac{1}{2}\rho v^3, \tag{1}$$

where ρ and v are air density and wind speed, respectively. P is usually regarded as a scalar though v is a three dimensional vector, since the wheel of horizontal axis wind turbines can always be adjusted to oriented perpendicular to wind direction.

The random single-site wind speed series at reference height v_0 can be regarded as

$$v_0 = \overline{V} + \Delta V. \tag{2}$$

Where, mean wind speed $\overline{V}$ is almost stable in the lifecycle of wind turbines; deviation ΔV can be treated as a random series reflecting the influences of short-term weather pattern and turbulent fluctuation. Then, the corresponding mean WPD at

Download English Version:

https://daneshyari.com/en/article/6764046

Download Persian Version:

https://daneshyari.com/article/6764046

Daneshyari.com