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Assessment of Onshore Wind Energy Resource and Wind-Generated Electricity Potential in Jiangsu, China

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Abstract

The onshore wind energy resource potential in Juangsu province was evaluated by annual wind power density and hours of effective wind speed, based on meteorological data from 1979 to 2008. Vestas V80-2.0MW (Megawatt) turbine was chosen as the reference wind turbine and wind-generated power potential was assessed from seasonal wind speed at 80m heights. Further, the Geographic Information System (GIS) software was used to exclude those unsuitable areas for installing wind turbines. Results show that Jiangsu has abundant wind energy resource, which is gradually increasing from the coast to the inland. The annual power production from the wind reaches 146 336 gigawatt-hours (GWh) or so in Jiangsu province, with Yancheng and Nantong along coast being two of the richest.

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Keywords: Wind energy;wind-generated electricity; wind turbine;assessment;

1. Introduction

Wind energy is clean, non-polluting and renewable. China is endowed with abundant wind energy resources, and its potential has been estimated at 3 200 gigawatt (GW) or so, of which 253 GW is deemed to be technically exploitable [1]. It is predicted that wind power could supply 15 percent of China's electricity by 2030 if the country invested $900 billion over that time period [2]. Regions with favorable wind energy resources are concentrated on the north and west regions of China and along coastal areas.

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Jiangsu province, located in the eastern coastal region of China, is confronting increasingly serious shortage of energy resources with the rapid growth economy. Due to its special geographic position, Jiangsu province has abundant wind energy resource. Exploitation and utilization of wind energy of Jiangsu province can contribute to its energy risk mitigation.

Wind energy resource assessment is an essential part of the development of wind power utilization. An accurate quantification and characterization of the available wind resources is necessary to design a wind farm optimally, providing the investors with the necessary confidence in financial feasibility and mitigating risks [3]. Wind energy resource potential has been widespread estimated in many regions of the world based on the wind data statistical analysis, for example, in Denmark [4], Taiwan [5], Canada [6], California [7], and China [8]. Although there have many studies focused on the theoretical wind resource potential by statistical analysis of historical record [5], little work has been done specifically for assessment of the wind-generated electricity potential in China or Jiangsu Province. The exploitation of wind energy resources is limited by many factors, such as topographical, political, economic, and technological and so on. However, most existing researches estimated only the theoretical potential and little attention has been paid to its technological available potential or wind-generated power potential. The objective of this paper is, therefore, to estimate the technological available potential of wind energy resources of Jiangsu Province.

2. Material and method

2.1. Data sources and processing

Meteorological data from 1979 to 2008, including daily average pressure, temperature, average wind speed, and air density, were download form the China Meteorological Data Sharing Service System (http://cdc.cma.gov.cn). Land-use map (1:250 000) and Chinese map (1:400 million) are provided by Institute of Geographic Sciences and Natural Resources Research, Chinese Academic of Science.

According to the requirements for wind energy assessment, representative year can be used to estimate the wind energy resource potential. The representative year refers to the mean value of the min, max and middle from wind speed records (1979~2008). The difference of wind energy density which is calculated by the representative year and the annual mean wind speed is no more than 4 percent [9].

2.2. Assessment of wind energy resource and wind-generated power potential

2.2.1 Assessment of wind energy resource potential

(1) Wind power density (WPD, W/m^2)

WPD is a truer indication of a site's wind energy potential than wind speed alone [10]. The WPD is defined as the wind power available per unit area swept by the turbine blades and is given by the following equation:

$$D_{wp} = \frac{1}{2n}\sum_{j=1}^{n}(\rho)(v_j^{3}) \tag{1}$$

Where n is the number of records in the averaging interval; ρ is the air density (kg/m^3); v is the wind speed value (m/s).

The effective WPD can be calculated by equation (1) using the effective wind speed (3~20m/s).

(2) Wind energy resource division

The criteria of wind energy divisions are as follows [11]:

Table 1 Indexes of wind energy divisions

Division indexes	Different wind energy areas			
	Rich	Comparatively rich	Available	Poor
Effective wind energy density at 10m ($W \cdot m^{-2}$)	>200	200~150	150～50	<50
Hours of effective wind energy (h)	>5000	5000～4000	4000～2000	<2000

2.2.2 Assessment of wind-generated power potential

● Sitting selection of wind farm

Site selection of wind farm often needs to exclude those areas with energy use restrictions [12]. Unfavorable areas for wind farm construction can be excluded by GIS software. The areas include those with (a) high altitude, (b) high slope, due to accessing difficulties, (c) areas near airports, for safety reasons, (d) protected areas (forests and national parks), due to legal constraints. In this study, we excluded the regions as follows: railway, forest, residential area and factories (with a buffering belt as wide as 500m); river, lake (buffering belt as wide as 400m); slope (maximum allowable slope 30%).

● Choosing of reference wind turbines

V80-2.0MW turbine) was chosen as the reference criterion for calculating wind-generated power potential. The rotor diameter is 80m, the same as the hub height. The cut-in wind speed is 4m/s and the cut-out is 25m/s. Its rated power is 2MW (http://www.vestas.com/en).

● Extrapolating wind speed at 80 heights

The hub height of the V80-2.0MW turbine is 80m. Wind speed needs to be extrapolated to 80m level based on the wind speed 10m level. The wind speed extrapolation formula is below:

$$v = v_0 \, [h/h_0]^{k} \qquad (2)$$

where v is wind speed at the height h (m/s), v_0 is wind speed at the anemometer height h_0 (m/s), h is height at which wind speed is measured (m), h_0 is anemometer height (10m) and k is the height exponent (0.14-0.3).

● Calculating of Wind-generated power

The distance between two wind turbines is usually assumed to three times of its rotor diameter. Based on the seasonal average effective wind speeds we estimated the number of the available turbines which might be installed in suitable places with the help of GIS analysis.

The annual wind-generated electricity potential can be calculated by equation 3. Wind-generated power formula is as following [13]

$$Q = K * V_m^{3} * A_t * T \qquad (3)$$

Where Q is total annual power generation (MW); K is 3.2; V is wind speed (m/s); A_t is the swept area of wind turbine rotor. Here it is 5 027m^2. T is the number of wind turbines.

3. Results and discussion

3.1. Wind resource potential

According to the abovementioned wind resource potential assessment, we can get the annual average WPD and hours of effective wind speed from the 14 national meteorological stations in Jiangsu province (Tab.2). Single station does not reflect the potential of wind resource potential across the region, but it can be handled with spatial interpolation for those regions without data. Here, the completely regularized spline was used to get the annual average WPD and hours of effective wind speed for the whole study regions. Figure 1 shows the distribution of wind energy in Jiangsu province.

The present investigation shows that Jiangsu’s wind energy resource is rich. The contour of wind speed near the coastal zone is basically parallel with coastline. The distribution of wind resource in Jinagsu province is decreasing from the coast to the inland (see Fig.1). The WPD in the 13 cities in

Jiangsu province is range from 50 to 100 W/m^2, with the east coastal areas being more than 150 W/m^2 (see Tab. 2, Fig. 1). According to Tab.1, Xuzhou, Nanjing, Wuxi, Changzhou and Zhengjiang region et al., belong to poor areas of wind resource, while Yancheng and southeast of Nantong have the most abundant wind energy. The available regions of wind resource are mainly located in the southeast of Suzhou, central and north-west of Nantong, north of Taizhou, southeast of Lianyungang and so on. The northwest, the west and south of Yancheng and central of Nantong belong to the comparatively rich areas (see Fig.1).

Table 2 Average WPD and number of hours of effective wind speed (H) of 14 meteorological stations in Jiangsu province

Station	Longitude (E)	Latitude (N)	WPD (W/m^2)	H (h)	Station	Longitude (E)	Latitude (N)	WPD (W/m^2)	H (h)
Dongshan	120.43	31.07	52	5125	Nanjing	118.78	32.04	40	4216
Shuyang	119.48	31.43	22	1824	Sheyang	120.25	33.76	224	6023
Changzhou	119.95	31.79	48	2200	Jiangying	120.26	32.98	41	2156
Lusi	121.6	32.07	156	6564	Huaian	119.15	33.28	25	3456
Nantong	120.88	31.98	51	4867	Xuyi	118.52	32.58	22	6428
Dongtai	120.28	32.85	52	5216	Ganyu	119.11	34.83	50	2400
Gaoyou	119.45	32.8	51	2300	Xuzhou	117.2	34.26	39	2226

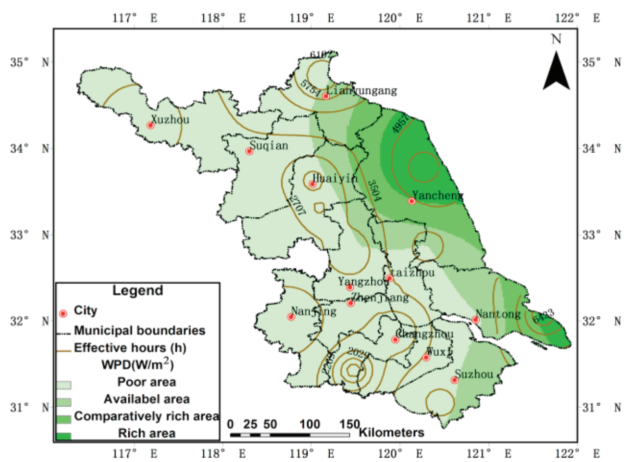

Fig.1 The distribution of wind energy resource in Jiangsu province

3.2. Wind-generated power potential

Using ARCGIS 9.3, suitable areas for installing V80-2.0MW in each city were estimated. Total available acreage reaches 1 813.4 km^2. Seasonal wind speed at 80 m height could be calculated by equation 2. Based on the seasonal wind speed at 80m height and the suitable region acreage of each region, the number of the Vestas V80 can be calculated. At last, the annually averaged power production from the wind could be computed by equation 3. Table 3 shows the calculated results.

The suitable acreage for installing Vestas V80 in Yancheng, Nantong region are 559 km^2 and 487.6 km^2, respectively, accounting for 57.72% of the total suitable acreage (see Fig.3). The potential of wind-generated power in Jiangsu province is abundant and the total annual average power production is 146 336 GWh. Yancheng is the hugest and its annual wind-generated power is 57 607.5 GWh. Nantong has also a relatively high potential of wind-generated power, and its annual wind generation is 38 847.5 GWh. There is a relatively less potential of wind-generated power in Zhengjiang, Wuxi, Changzhou and so on. Tab.3 shows that the onshore wind power potential in Jiangsu is greatest in winter, lowest in autumn.

Table 3 Seasonal wind speed and wind-generated power potential in Jiangsu province

Study regions	Suitable acreage (km^2)	Number of wind turbine	Seasons power production (GWh)				Annual power generation (GWh)
			Spring	Summer	Autumn	Winter	
Changzhou	32.9	727	352.31	304.3	184.2	736.7	1 577.38
Huaian	77.6	1 716	945.36	586.1	321.4	1 815.1	3 667.98
Lianyungang	112.5	2 489	1727.1	1 178.8	630.5	3 180.1	6 716.48
Nanjing	35.8	791	313.6	252.7	148.1	801.5	1 515.88
Nantong	487.6	10 785	7365.6	5 940.0	4 158.0	2 1384	38 847.5
Suzhou	84.2	1 862	2153.2	1 743.1	1 599.6	7 710.6	13 206.5
Suqian	61.7	1 365	871.8	541.10	345.7	1 984.1	3 742.71
Taizhou	110.3	2 439	1665.9	1 155.4	725.5	3 869.2	7 415.98
Wuxi	23.85	527	220. 8	156.9	87.2	604.2	1 069.05
Xuzhou	118.0	2 610	2185.2	891.3	345.0	2 070.2	5 491.76
Yancheng	559.0	12 363	11 303.6	7 626.5	5 992.3	32685.1	5 7607.5
Yangzhou	85.3	1 886	997.3	664.9	415.5	2410.1	4 487.84
Zhenjiang	24.6	544	239.9	173.9	96.0	479.8	989.5
Total	1 813.35	40 104	30 121	21 215	15 049	79 731	146 336.1

4. Conclusions

There are abundant wind energy resources in Jiangsu province. Eastern coastal areas of Jiangsu has the hugest of wind resource, its annual WPD is more than 200W/m^2, and the hours of effective wind speed are not less than 5000h. Jiangsu province has huge potential of wind-generated electricity and the annual wind power generation is 146 336 GWh. Much of the potential of wind power in Jiangsu province is located at its eastern coastal areas.

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