Solar Energy Resource Assessment of an Offshore Photovoltaics in Shandong

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Abstract: This article takes a certain offshore photovoltaic project in Shandong as an example, and uses the reference meteorological station method and SolarGIS database query method to calculate the solar energy resources in the photovoltaic field area. The average annual total solar radiation in the site area is 5009.8MJ/m^2·a. Through analysis, it can be concluded that the photovoltaic field area is rich in solar energy resources and belongs to Class C area according to the "Assessment Method for Solar Energy Resources" (GB/T 37526-2019), which has development value.

Keywords: Solar Energy Resource; sunshine hours; solar radiation

1 Introduction

Usually, large-scale onshore photovoltaic projects require a significant amount of land area and land resources, while offshore photovoltaic power generation is a new energy utilization and resource development model that moves "photovoltaic power stations" from land to sea and uses photovoltaic technology to establish power stations in the ocean. It has the characteristics of high power generation, low land occupation, and easy integration with other industries.

Compared to onshore photovoltaics, marine photovoltaics have natural environmental advantages. The water surface is open without obstructions, and the sunlight is long and fully utilized, which can significantly increase power generation. The power generation of onshore photovoltaics is 5% -10% higher than that of onshore photovoltaics. Offshore photovoltaic power stations are divided into two categories: fixed pile foundation and floating type. Generally, if the water depth is less than 5m, pile driving frame height installation is used, and floating installation can be used for water depths above 5m. At present, offshore photovoltaics are mainly based on pile foundations.

The offshore photovoltaic field used in this paper is located along the coast of Shandong Province, with an offshore distance of approximately 15km in the central area of the photovoltaic field. The depth of the chart is 4-5m, and the total planned sea area is 20km^2. This project plans to use a fixed pile foundation support structure to place photovoltaic modules, with a planned capacity of 850MWp.

A lot of researchers had study the solar energy in China and other counties[1-11]. This paper used reference station calculation method to analysys the solar energy of an offshore photovoltaics in Shandong.

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2 Conditions of Solar Energy Resources in Shandong Province

Currently, there are only three solar radiation stations in Shandong Province, including Jinan, Fushan, and Juxian. There are currently no solar radiation observation stations in the project location. According to the daily variation analysis of the average total solar radiation, the total radiation increases linearly from the end of January to the maximum value at the end of May or early June; From mid to late July to early October, the total radiation remained at 15MJ/m^2·d, with three major oscillations during this period; From early October to mid to late November, the total radiation decreased linearly; By late January, the radiation level remained low and the daily changes were gradual.

According to data analysis from 1961 to 2000, the interannual variation range of solar radiation at Jinan Station is between 4147 and 5777 MJ/m^2·a, while the interannual variation range of solar radiation at Fushan Station is between 3900 and 5580 MJ/m^2 · a, and the interannual variation range of solar radiation at Juxian Station is between 3920 and 5720 MJ/m^2·a .

3 Analysis of solar energy resources at the site

Due to the lack of measured solar radiation data at the site at this stage, Comparing the geographical location and climate environment of the site with three solar radiation stations in Jinan, Fushan, and Juxian counties in Shandong Province, it is believed that the climate conditions in Jinan station are more similar to the site area. Therefore, Jinan station is selected as the solar radiation reference station for this project. The empirical coefficient is calculated based on the measured data from the Jinan Solar Radiation Station, and then the total annual solar radiation in the site area is calculated using the observed data from the meteorological station over the years. The comparison analysis is conducted with the data from the Meteonorm and SolarGis databases.

3.1 Reference Station Calculation Method

According to the "Assessment Method for Solar Energy Resources" (GB/T 37526-2019)[12], if there is no national level radiation observation station that meets the requirements near the evaluation target, a meteorological observation station that meets the spatial representativeness requirements and has sunshine hours can be used as a reference station, and the monthly total horizontal radiation can be calculated based on its recorded long-term series of sunshine percentage data. The calculation formula is as follows:

$$GHRm=EHRm(a+b•s)$$

In which,

GHRm—Monthly total horizontal radiation(MJ/m^2)；

EHRm—Solar radiation from the lunar extraterrestrial horizontal plane(MJ/m^2)；

a,b—empirical coefficient,which is calculated using statistical methods based on the measured data of the nearest national radiation station to the reference station;

s—Monthly sunshine percentage measured by the reference station(%).

According to the measured data of meteorological stations around the photovoltaic field, the monthly average sunshine hours are shown in Table 1 and Figure 1.

Table 1 Monthly Average Sunshine Hours at Meteorological Stations

Month	January	February	March	April	May	June
Sunshine Hours (h)	172.7	173.8	212.8	227.6	248.1	225.7
Month	July	August	September	October	November	December
Sunshine Hours (h)	187.1	192.3	212.3	204.6	170.4	165.1

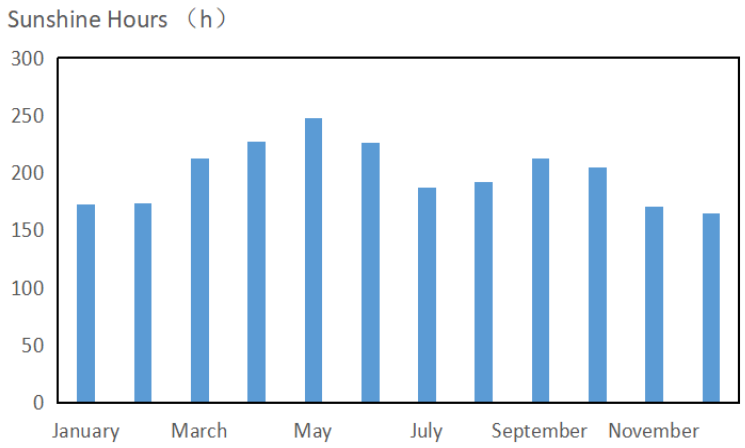

Figure 1 Monthly Average Sunshine Hours at Meteorological Stations

Based on the measured data of Jinan Sunshine Station, the empirical coefficients a and b were calculated separately, as shown in Table 2 . Then, the characteristics of the total solar radiation over the years in the site area were calculated and statistically analyzed using the observation data of the meteorological station, as shown in Table 3 and Figure 2.

Table 2 empirical coefficients a and b

Month	January	February	March	April	May	June
b	0.4458	0.3366	0.2467	0.2650	0.4143	0.3425
a	19.7407	24.6078	31.9175	32.1131	24.7194	27.9872
Month	July	August	September	October	November	December
b	0.3127	0.3014	0.3361	0.3348	0.3786	0.4074
a	27.8257	27.0197	26.1551	25.4221	24.3072	22.3454

Table 3 Monthly total radiation of the site

Month	January	February	March	April	May	June
Total Radiation(MJ/m^2)	249.7	297.1	430.4	515.1	615.7	581.6

Month	July	August	September	October	November	December
Total Radiation(MJ/m^2)	535.8	502.4	455.9	354.5	252.4	219.2

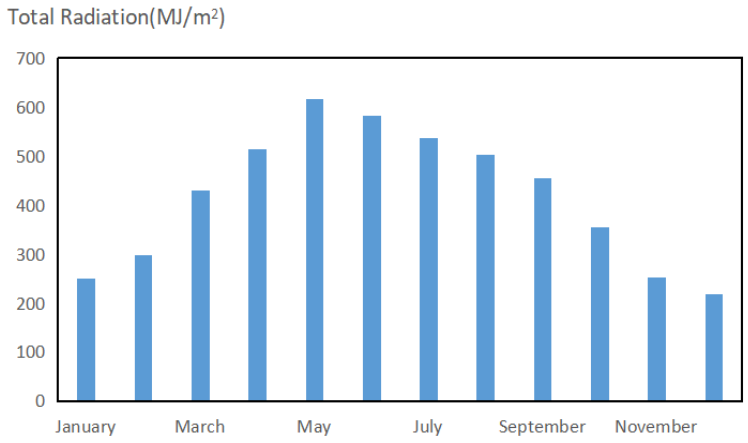

Figure 2 Monthly total radiation of the site

According to calculations, the average annual total solar radiation in the site area is 5009.8MJ/m^2·a.

3.2 SolarGIS database query method

SolarGIS is a solar resource assessment tool developed by Solargis S.R.O. in Europe. It utilizes satellite remote sensing data, GIS (Geographic Information System) technology, and advanced scientific algorithms to obtain a high-resolution database of solar resources and climate factors, covering Europe, Africa, and Asia. It has been widely used in the early development, resource evaluation, and power generation calculation of photovoltaic, concentrated photovoltaic, and photothermal projects.

According to SolarGIS, the total annual radiation amount of the site area is 5286.3MJ/m2·a .

4 Assessment of solar energy resource level

According to "Assessment Method for Solar Energy Resources" (GB/T 37526-2019), solar energy resource level is assessed as table 4.

Table 4 Annual radiation level of total solar radiation

Grade name	Grading threshold values (MJ/m2·a)	Grade symbol
Most aboundant	G≥6300	A
Very aboundant	5040≤G＜6300	B
aboundant	3780≤G＜5040	C
common	G＜3780	D

According to SolarGIS, the site area belongs to the Class B area of national solar energy resources, which belongs to a very aboundant level and has good solar energy development value.

According to reference station calculation method, the site area belongs to the Class C area of national solar energy resources, which belongs to a very aboundant level and has good solar energy development value.

For safety reasons, it is recommended to use reference station calculation method result.

It is recommended to establish a solar observation station in the site area and verify the calculated data using measured data in order to optimize the design of this project.

5 Conclusions

This paper used reference station calculation method to analysys the solar energy of an offshore photovoltaics in Shandong, and then compared the result with SolarGIS. According to the result, the site area belongs to the Class C.

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