Proceedings of the 2023 International Conference on Mechatronics and Smart Systems
DOI: 10.54254/2755-2721/9/20230060

Research on environmental and resource benefits of offshore multifunctional power generation platform

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Abstract: With the development of science and technology, land resources have been over-exploited and cannot meet the needs of development, so people gradually turn to the ocean for development. The ocean not only occupies two thirds of the earth, but also contains a variety of rich resources. They not only meet people's huge demand for energy, but also most of the resources in the ocean are green and renewable energy, which not only reduces the cost of resource development to a certain extent, but also reduces the impact on the environment in the development process. An offshore multifunctional power generation platform is designed in this paper. The impact of chemical substances produced when the anti-corrosion coating on the surface of the platform on the Marine environment is analysed. Compared with the construction cost of offshore resources development, the reduction of carbon emissions and the impact of offshore platforms on the marine environment were studied respectively. The final cost per kw of the platform is at the average level of an offshore power generation project. Carbon emission reduction is much less than traditional onshore power generation projects. The pollution to the marine environment is also within the provisions of the marine pollution index.

Keywords: offshore multifunctional power generation platform, carbon emission, cost evaluation, environmental implication.

1. Introduction

In the 21st century, with the depletion of land resources and the immaturity of new energy development technology, human have begun to set their sights on the ocean. Covering 71% of the earth's surface area, the ocean is a huge treasure trove of resources, such as mineral, energy, biological, water resources and so on. Therefore, the development and utilization of marine resources has gradually become the development priority of various countries. Compared with the development of terrestrial resources, large reserves, renewables and large distribution have become the biggest advantages of marine resources. Among them, offshore wind energy, as one of the main offshore energy sources developed at this stage, is transformed by offshore wind turbines. As the national with the largest installed offshore wind capacity [1]. China added 14.2GW of new offshore wind capacity in 2021, an increase of 351% over in 2020 [2]. Solar energy is also widely used on land, so the technical conditions have been very mature, in the process of the development of marine resources, the platform can give full play to the characteristics of unobstructed and widely distributed in the ocean, and efficiently use solar energy. By combining offshore wind power generation installations with solar power generation units, a new offshore multi-purpose power generation platform is designed. The platform consists of four large wind turbines rated at 6 MW and photovoltaic panels with a total working rate of 2 MW, and a transparent hollow hemisphere is also placed as a concentrating device on the platform where the photovoltaic panels are placed in the middle.

At present, human research on ocean floating platforms is still in a stage of development research. Offshore wind power generation is also in an immature stage, and a complete system for the installation [3], operation and maintenance of such installations has not yet been formed, so this will make the cost of this platform and the subsequent operating costs difficult to calculate. Moreover, with the development and utilization of marine resources, the problem of marine pollution also arises. The dumping of marine litter, the transportation of chemicals at sea and the leakage of oil and some harmful gases at sea have all become the main of marine environmental pollution [4]. Because the offshore platform has been working in seawater for a long time, and because its whole is basically composed of steel structure, anti-corrosion measures are essential. The part that is in direct contact with the ocean often has a chemical reaction due to the contact between the anti-corrosion system and seawater, resulting in pollution ocean [5]. The pollution caused by offshore platforms to the marine environment will detect the unique chemical substances emitted when they come into contact with seawater according to the chemical properties of different anti-corrosion systems [5]. Therefore, the impact of the platform on the marine environment is also a problem that needs to be solved.

In order to solve the problems of this platform, a 3D model of the platform is made according to the equipment reference. The cost of this platform and its carbon emission in the life cycle is evaluated.

2. Method

2.1. Platform design concept and economic benefit evaluation

The offshore multifunctional power generation platform studied in this paper combines wind power generation with solar power generation, using four fans with rated power of 6 mw and photovoltaic power generation panels with total power of 2 mw. In order to make full use of light energy, a transparent hollow half-sphere device is installed above the middle platform; In addition, according to the light reflection principle and the calculation of the sun's incidence Angle height, a light reflection device is placed in the hemispheres to reflect the solar rays at various periods to the photovoltaic panel as much as possible [6]. Because the overall weight of the platform is very high, the design uses a spar type floating platform, and the diameter of the buoy is enlarged to reduce the draft depth, thus reducing the overall cost. In order to achieve the stability required during the work, concrete ballast was carried out at the bottom of the buoy, and the center of gravity of the overall structure was adjusted below the center of buoyancy.

In order to better calculate its cost and evaluate it, the whole platform is divided into fan unit, photovoltaic panel, platform, riser, buoy and other parts according to the 3D model. The material and device purchase costs of each part are calculated respectively, and then the corresponding installation and labor costs are added according to the size, and the total cost is finally obtained. Its economic value is evaluated by dividing the total cost by the total power of the entire platform to find the cost per kw of electricity, and then comparing it with the economic cost per kw of offshore wind power projects in Europe and other countries.

2.2. Cyclic carbon emission method

In order to study the specific carbon emission of this device, this paper will divide the whole process into manufacturing, transportation, installation, operation, waste disposal and recycling, and then calculate the carbon dioxide emission of the whole life cycle of each process separately. Because the whole fan unit is basically composed of copper, iron, steel, aluminum and other metals, so in the manufacturing process will produce a lot of carbon dioxide. According to the number of main materials, carbon emission factors and emissions required in the manufacturing process of 24 MW wind turbine, the life cycle carbon dioxide emissions are calculated. In the 23 transportation process, the equipment of the system mainly relies on road transportation and ship transportation, which will consume gasoline and diesel, so the carbon emissions of diesel and gasoline are calculated. Inspection and maintenance of wind power systems, which consume electricity and emit carbon dioxide. In the waste recovery period, part of the fan materials can be recycled, although to a certain extent to reduce carbon emissions, but due to landfill combustion will increase carbon emissions. For carbon dioxide emissions in the life cycle of photovoltaic power generation panels, its algorithm is similar to that of wind turbines, but mainly considers carbon dioxide generated by their constituent materials, such as batteries and silicon crystals [7]. Therefore, the overall cycle carbon emission is calculated as follows [8]:

$$E = E_1 + E_2 + E_3 + E_4 \tag{1}$$

Where, E is the total life-cycle greenhouse gas emissions. E_1 is the greenhouse gas emissions of equipment. E_2 is greenhouse gas emissions during construction.E_3 is greenhouse gas emissions from operations and maintenance.E_4 is greenhouse gas emissions from the demolition process

2.3. *Impacts of platforms on the marine environment*

In general, the impact of offshore platform anti-corrosion systems on the Marine environment is due to the organic coatings and metal materials in the anti-corrosion system. All kinds of phenolic compounds such as tert-butylphenol, octyl phenol and nonylphenol in organic coatings, compounds such as xylene, ethylbenzene and methyl isobutyl ketone used as paint solvents, as well as substances such as phenol, diamine and polyamine used as viscosity regulators, hardening catalysts or hardeners for epoxy resins, are included in the Marine environment assessment list. The metal emission is mainly due to the adoption of sacrificial anode to protect the cathode in the anti-corrosion system. The amount of sacrificial anode required by the cathodic protection system is determined by the following formula:

$$Ma = \ Icm \times T \times 8760\ /\mu \times \varepsilon \tag{2}$$

Where, Ma is the number of sacrificial anodes required for cathodic protection. I cm is the mean protective current. T is designed life. μ is sacrificial anode utilization factor. ε is electrochemical capacity of the sacrificial anode. Among the anode metals, aluminum, zinc and indium are the main metal elements that can cause pollution to the Marine environment. Due to the low solubility of aluminum in the ocean, it mainly exists in the form of aluminum hydroxide and tetrahydroxy aluminate, which can also combine with fluorine or dissolved organic matter to form organic chelates. Gillmore et al. studied the effects of dissolved and precipitated aluminum on different diatoms and proved that it could cause toxicity [9]. Experiments of Rousseau et al showed that during the zinc anode dissolution process, zinc ions in water and precipitation increased in the form of hydroxide, and also adhered to suspended matter in the form of complex [10]. Since the toxicological effects of zinc are dose-related, many coastal countries have included it in environmental quality standards, such as the upper limit of zinc content in the standards of seawater quality, Marine sediment and Marine organisms of China. Indium only makes up 0.015% to 0.04% of sacrificial anodes, but because of its low concentration in the Earth's crust, dissolution of Indium-containing sacrificial anodes may instead be an important external source of indium in the ocean compared to the natural environment. Toxicological studies of indium on industrial workers have shown that indium can produce certain toxicological effects. For offshore wind power infrastructure with different structures, the emission of aluminum, zinc and indium due to the dissolution of sacrificial anode is about 334 ~ 3663 kg, 17.6 ~ 192.8 kg and 0.05 ~ 0.58 kg [5].

3. Result

3.1. *Costing result*

The cost is as shown in Table1. The total purchase fee and installation fee of the fan are 115.8 million yuan and 50 million yuan, respectively; the total purchase fee and installation cost of photovoltaic boards are 19.4 million yuan and 4 million yuan; The cost and installation costs were 162.7 million yuan and 15.5 million yuan; labor costs were 69 million yuan. The total cost is the total cost of the above constituent of 437.2 million yuan. In Europe, where wind technology is more sophisticated, wind turbine projects cost between €1,300 and €2,400 per kilowatt. The average cost of the platform is 2,296 euros per kilowatt within the normal cost range

Table 1. Cost conclusion

	Purchase fee	Installation fee
Fan (6 MW)/10,000	11,580	5,000
Photovoltaic board/10,000	1,940	400
Platform, riser and floating tube, etc./10,000	16,270	1,550
Artificial cost/10,000	6,900	
Total cost/10,000	43,720	
Total power	26000kw	
Cost per kw/10,000	1.68154	

3.2. Cyclic carbon emission

During transportation, the system's equipment mainly relies on road transport. Gasoline and diesel consumption, diesel carbon emission factor of 2.73 kg CO_2/L. 1000 workers are required during the installation process, working for 6h. CO_2 22.4L per person per hour. Wind power systems need to be inspected and repaired during operation, resulting in carbon emissions due to electricity consumption. Based on the annual energy consumption of wind farm operation, the CO_2 emission factor of thermal power is 0.81 kg/(kW·h).

In the manufacturing process of photovoltaic power generation systems, carbon emissions of materials such as industrial silicon, polysilicon, silicon wafers, cells, cell modules and photovoltaic balance modules are mainly considered. Among them, the carbon emission factor of fuel is 2.73 kg CO_2/L, and the final emission of the photovoltaic transportation stage can be calculated. The installation process of photovoltaic power generation system requires 100 workers and 40h of work. The calculation is the same as for wind power installation, resulting in CO_2 emissions during installation. During the operation of the system, the failure rate is very small, the energy consumption can be ignored, and the carbon emission is 0.

Calculating the ratio of life cycle carbon emissions to life cycle electricity generation, it is concluded that the CO_2 emission intensity of wind power generation system, photovoltaic system and wind photovoltaic power generation system is 24.08, 32.58 and 29.20 g/(kW·h), respectively, which is much lower than the carbon emission intensity of thermal power generation [810 g/(kW·h)] The CO_2 emission intensity is shown in the Table 2.

Table 2. Carbon dioxide emissions

Wind power generation systems	Photovoltaic systems	Wind and solar power generation system
24.08 g/(kW·h)	32.58 g/(kW·h)	29.20 g/(kW·h)

3.3. Metal emission estimation

Using the formula mentioned above, it can be calculated that the weight of anode sacrificed per year is 24.8 t for a single column structure with an underwater area of 1600 square meters and a buoy of 2000 square meters, and the annual emission of aluminum is 942.4 kg, zinc is 49.6 kg, and indium is 0.1488 kg. According to the proportional relationship, the metal emission of this platform is shown in Table 3 [5].

Table 3. Metal discharge

	Four posts	Float bowl
Underwater area square meters/m^2	3600	900
Sacrificial anode/t	19.8	7.2
Annual emissions of aluminum/kg	752.4	273.6
Zinc missions of aluminum/kg	39.6	14.4
indium missions of aluminum/kg	0.1188	0.0432

4. Discussion

5.1. Construction cost

The cost of the offshore multifunctional power generation platform of 2,296.77 euros per kilowatt is in the middle of the average cost of 2,300 euros per kilowatt for wind turbine projects in other European countries. As the technology of wind power becomes more mature, the cost of wind turbines will be greatly reduced. As a major wind energy development project at the present stage, the number of offshore fan will increase rapidly in the next five years, and the selection of fan materials will be more reasonable. Carbon brazing material lightweight, high strength, perfect fit fan blade upsizing, lightweight development trend; PVC sandwich material can also be used in the construction of the platform, which is not only light in weight but also high in strength. On the premise of reducing the cost of raw materials, it also greatly reduces the difficulty of shipping and construction operations at sea, thus effectively reducing the installation cost. But the benefits of these materials have been tested under strict conditions, and there is no guarantee that they will work effectively if they are put into the ocean and combined with other materials. Therefore, if we want to apply these new materials to the construction of ocean engineering, we still need a lot of manpower, material resources and financial resources to do experiments and tests in the relevant environment. Only when we get stable results can we apply them to the actual engineering.

5.2. Carbon emissions

In the operation and maintenance phase, the on-grid electricity of the wind farm theoretically replaces this part of the thermal power generation, resulting in carbon emission reduction. According to the estimated on-grid electricity of wind power during the operation period, the carbon emission reduction in the life cycle can be calculated, and the carbon emission recovery period of the wind farm can be calculated by comparing the CO_2 emissions of the whole life cycle. In this project, the carbon emission recovery period is less than 8 months, about 0.7 years, without considering the recycling of equipment materials, and the carbon emission recovery period is about 6 months, about 0.5 years, under the premise of considering the recycling of equipment materials. Based on the estimated power generation over the 20-year life cycle, the carbon emission reduction during the life cycle can reach 1.36×106 tCO_{2e}. However, this study has certain limitations, from the carbon footprint calculation model, increasing the proportion of materials and equipment recycling of retired wind turbines will significantly reduce the carbon emissions of the whole life cycle of the wind power system. At present, this project has not yet been decommissioned, the wind power industry has not yet entered a large-scale decommissioning period, there is very little information and data on the decommissioning of wind turbines, and relevant research can be further deepened. Through the calculation of the carbon footprint of wind power systems, carbon emissions during their life cycle mainly come from the process of obtaining raw materials. The carbon emission coefficient of various materials is closely related to the energy consumption level, resource recovery ratio and renewable energy use ratio of various materials in the mining, production and manufacturing links of various materials. These industries are usually high-energy-consuming industries, so reducing the comprehensive energy consumption of various materials, increasing the proportion of waste recycling and increasing the proportion of renewable energy use will significantly reduce the total CO_2 emissions during the life cycle of the wind power system and help downstream related products achieve carbon neutrality. The emission factors of each material used in this study reflect the comprehensive level of the production and manufacturing of various materials worldwide, so the use of low-energy, advanced processes at various stages of the life cycle will also help reduce the overall carbon emission level. In the calculation of carbon emissions throughout the life cycle of wind farms, the carbon emissions generated in the production and construction stages of wind turbine materials account for a large proportion, and the recycling and disposal of various materials of wind turbine equipment during the decommissioning period has a significant impact on carbon emissions. According to the carbon emission model in this paper, the carbon recovery period of the wind power generation system in the whole life cycle without considering material recovery and considering material recovery is about 0.7 years and 0.5 years, respectively, that is, it only takes a short time to achieve carbon neutrality in the life cycle of the system, which has good low-carbon benefits compared with traditional fossil energy power stations. Through calculation and comprehensive analysis, it can be seen that the three effective ways to reduce the carbon emissions of the life cycle of wind power systems are: first, increase the proportion of renewable energy consumption in the production and manufacturing of raw materials; Second, improve the energy efficiency level of high-energy-consuming industries; Third, vigorously develop the circular economy and improve the level of waste recycling.

5.3. The impact of the Marine environment

According to China's seawater quality standard [11] and Marine sediment standard [5], the limit value for metals is 0.05 mg/L for second-class seawater, while the metal discharged by the platform is 0.036 mg/L. The results show that the impact of the platform on the Marine environment is within the acceptable range. Since the technology to prevent metal rust from seawater is still in the development stage, such problems can only be solved by changing the type of raw materials and adding anti-corrosion layer on the outside. Therefore, the anti-corrosion layer formed by metal elements and organic compounds in the platform is one of the main factors causing marine pollution, so it is very necessary to develop a new kind of material, just like nanomaterials. Not only does it have the same strength and stiffness as steel, but it doesn't react with seawater, which in turn causes corrosion problems. This material can not only greatly reduce the weight of the whole platform, but also reduce the impact on the petrel environment. However, the current material technology has a certain degree of difficulty for the research and development of this new material, and the research and development cost is very huge, so it is difficult to develop this kind of material in a short time.

5. Conclusion

With the decrease of land resources, the development of Marine resources is the general trend. There are many kinds of resources in the ocean, so there are many kinds of corresponding development platforms. Wind power and solar power will be the main offshore resources to be developed because of their wide distribution and high energy. The platform studied in this paper is an offshore multifunctional power generation platform that combines wind power generation with solar power generation. The feasibility of this platform is explored by studying its development cost, carbon emission and factors affecting the Marine environment. The development cost of the platform is lower than that of most traditional wind power generation installations, and the greenhouse gas emissions of the platform during the whole life cycle are far less than that of traditional land-based installations such as coal power generation. In addition, under the premise of ensuring high working efficiency, the pollution caused by this platform to the Marine environment is also very small, so it has a good development prospect. However, due to the current offshore construction system is not perfect, and many technical aspects have not yet met the requirements, so if you want to better realize the combination of wind power generation and solar power generation, people still need to continue to improve the construction system of the entire ocean engineering operation, and develop more suitable for the Marine environment of building materials.

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