New wind Power Bridge based on double rotor wind turbine

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Keywords: Wind power generation, wind bridge technology, power generation efficiency.

Abstract: In order to make full use of the valley winds in the western region and the ocean winds in the southeast coastal areas, and to broaden the application of wind power, we have designed a new wind power bridge technology based on dual-rotor wind turbines. This program relies on the bridge structure and makes full use of the wind field where the bridge is located to generate electricity. Install an innovative double-rotor fan on the bridge, which can greatly improve the wind energy utilization coefficient, and provide more uniform force to the bridge than the general fan to ensure the safety of the bridge; small and medium-sized wind turbines without a yaw mechanism are installed under the bridge. The high wind speed generated by the natural narrow tube effect of the bridge support structure improves the power generation efficiency, and connects the charging coil for the small fan, which provides support for the wireless charging technology of the electric vehicle in the future, and realizes the immediate use of the electric energy.

1. Development background and significance

At present, wind power generation has become the third largest form of power generation in China. The Outline of the National Medium- and Long-Term Science and Technology Development Plan states that "the proportion of renewable energy in China's energy consumption will reach 16% in 2020" [1], and the use of wind power generation has broad research space and development prospects.

However, a large number of high-quality wind farms in China have been developed and utilized, and the annual average wind speed of the remaining wind farms is unsatisfactory. China's wind power has officially entered a transition period. The current wind power industry is in desperate need of an ideal wind farm capable of arranging wind turbines over a large area. Therefore, we have turned our sights on bridges with natural "stubbing effects".

The bridge is generally constructed in the shortest distance between the two land areas. The axial cross-sectional area is the smallest. The natural narrow tube effect is formed before and after the bridge, which increases the average wind speed and forms a high-quality natural wind field. On the bridge deck, we designed the dual-rotor wind turbine into the bridge support structure, effectively utilizing the bridge wind speed, on the one hand sharing the basic structure with the bridge, saving consumables, and preventing the bridge from being fixed in one-way force, slowing down The fatigue damage of the bridge increases the stability of the bridge; on the other hand, the dual-rotor wind turbine has high power, high utilization of wind energy and large annual power generation. Below the bridge deck, a small fan is integrated into the bridge bracket to make full use of the idle space to generate electricity. Not only does energy are used effectively, but it also adds to the beauty of the bridge.

Promote wind power bridges, on the one hand, increase the source of power supply, improve the grid-connected capacity of wind power, alleviate the shortage of power supply in some areas, effectively reduce the cost of electricity, and achieve efficient resource allocation. On the other hand, reducing the use of oceans, weakening the impact on marine life, facilitating the maintenance of the unit, adding new forms of wind farm construction, providing new directions for future development of wind power buildings, contributing to better wind power generation. The alternative to traditional thermal power generation to achieve sustainable social development.

2. Design Plan

2.1 Overall design ideas

In the western part of China, especially in the valley, the wind resources are good but cannot be utilized. The sea-crossing bridges in the eastern coastal areas often have sea breeze blowing, and wind energy needs to be used. In response to such phenomena, we propose a "new wind power bridge based on dual-rotor wind turbines" installation scheme as shown in Figure 1.

Figure 1 New wind power bridge based on dual rotor wind turbine

This program is mainly divided into two parts: power generation on the bridge and under the bridge. A single-rotor wind turbine is installed under the bridge. The theoretical limit of wind energy utilization of the currently known single-rotor wind turbine is the Bates limit Cp=59.3%.[2] Due to the optimization of blade design of wind turbines, modern control theory and the application of high reliability electronic components, the actual performance of wind turbines is gradually improving. However, it should be emphasized that the premise of the Bates limit is the use of a single, non-ducted rotor. Due to cost considerations, the main research direction of the current wind energy industry is in the design of single rotor (HAWT). Under the premise of scarce resources in today's wind farms, how to use wind resources more effectively becomes an urgent problem to be solved.

According to the research, the dual-rotor turbines featuring two sets of rotor systems are more aerodynamic analysis than the traditional single-rotor horizontal axis wind has a higher wind energy utilization factor and can exceed the Bates limit.[3] Because the aerodynamic thrust mostly occurs at the tip of the blade, the auxiliary wind wheel in the upwind direction can compensate the aerodynamic thrust of the main wind wheel in the downwind direction at the center of the wind wheel. The auxiliary wind wheel and the main wind wheel rotate in opposite directions, and the gear ratio is also set such that each rotor can rotate at an optimum tip speed ratio. Finally, the influence between the rotors is minimized by determining the distance between the rotors. And Newman extended the Rankine-Froude momentum theory to the study of two-rotor wind turbines for calculating the Bates limit.[4] The maximum Cp of a two-rotor wind turbine of the same size was calculated to be 64%, exceeding the Bates limit of 8%. It is fully proved that the use of this fan can make better use of the superior wind resources between the ocean and the valley to achieve higher utilization of wind energy. At the same time, since the wind turbines installed on the bridge are arranged in a single row, there is no need to consider the wake. After the impact of the effect, after careful calculation and comprehensive trade-offs, we decided to build a two-rotor wind turbine as shown in Figure 2 on the wind power bridge.

Figure 2 Double rotor wind turbine

Under the bridge, we use small and medium-sized wind turbines (10kW-1000kW), which are mainly used in places with low wind speed, such as the position below the bridge deck, and through the arch under the bridge. The combination of structures can enhance the stability of the bridge itself. Due to the relatively mature technology of small and medium-sized wind turbines, the high cost of permanent magnets under medium and low power, and the ease of maintenance on bridges, the unit uses doubly-fed units.

The new wind power bridge makes full use of the valley wind formed between the valleys in the western region, and the sea breeze blown over the ocean. Two wind turbines and two rotor wind turbines are installed on the bridge structure. It can be applied to bridges between western valleys and coastal bridges in the eastern coastal areas. It converts wind energy that cannot be used by people in the valleys and oceans into electric energy, to solve the problem of uneven power generation in the eastern and western regions, and to broaden the field and mode of power generation. New ideas for reducing the pressure on the West-East Power Transmission Project.

2.2 Unit design

The system is mainly composed of four parts, which are the normal bridge deck, the support structure of the bridge, the double-rotor wind turbine on the bridge and the power generation structure under the bridge.

2.2.1 Bridge deck design

For the bridge deck, the pavement design of the bridge is carried out in strict accordance with the "Technical Standards for Highway Engineering" and "General Specifications for Design of Highway Bridges and Culverts". At the same time, the electromagnetic components of the power supply coil are laid on the bridge surface, and the non-radiative electromagnetic resonance is used to wirelessly charge the vehicle through the bridge.

2.2.2 Bridge support structure design

For the support form of the bridge, analyze the bridges, cable-stayed bridges, arch bridges and suspension bridges of the main bridges in the bridges with large spans.

1) The beam bridge is more and more rare in the current long-span bridge because of its self-importance and the greater the ratio of its self-weight. At the same time, we should point out that on the sea-crossing bridge such as the Zhuhai-Hong Kong-Macao Bridge, the combination design of the beam bridge and the cable-stayed bridge is used. This form is also very beneficial for the application of this project.

2) Cable-stayed bridges are becoming more and more mainstream in today's long-span (200-800m) bridges due to their large spanning capacity, reasonable force and high stiffness. However, since the cable-stayed bridge is a high-order statically indeterminate structure, the calculation of the bridge load is complicated. At the same time, when the wind bypasses the bridge, an unsteady airflow is formed. This airflow with varying speed and direction may cause low wind

speed resonance and high wind speed flutter. Space structure model is needed for wind resistance analysis. Experimental verification. This kind of structure is more complicated and can be used as the main structural form of the wind power bridge when the technology is mature in the future, but this project does not adopt this form for the time being.

3) The arch bridge has a large spanning capacity, a simple structure and good durability, so the maintenance cost is low. However, the lower arch bridge is abandoned because its arch structure is too high to interfere with the installation and operation of the dual-rotor wind turbine. The arch structure of the upper arch bridge is suiTable, but due to its own weight, and for the bridge deck The structure of the supporting truss is high and needs to be used after a certain combination of transformations.

4) Suspension bridges use suspension cables as the main load-bearing structure, and their structures are lighter. They can use relatively small materials to span longer distances. Compared with the low-rise construction of the cable-stayed bridge, the economy is good. The construction of the suspension bridge is flexible and suiTable for construction in high winds and earthquake zones. However, the suspension bridge is not strong enough.

Based on the above factors, we can achieve the combination of the advantages of the two by using the suspension design on the bridge and the tangential structure of the bottom end of the wind turbine under the bridge deck to jointly complete the support structure of the new wind power bridge. ,As shown in Figure 3. This three-dimensional modeling uses the design of the suspension bridge + arch bridge, and can also be applied to bridges of other forms or combinations. On a specific bridge, multiple sets of wind turbine equipment can be built according to the length and needs to achieve high-power grid-connected power generation.

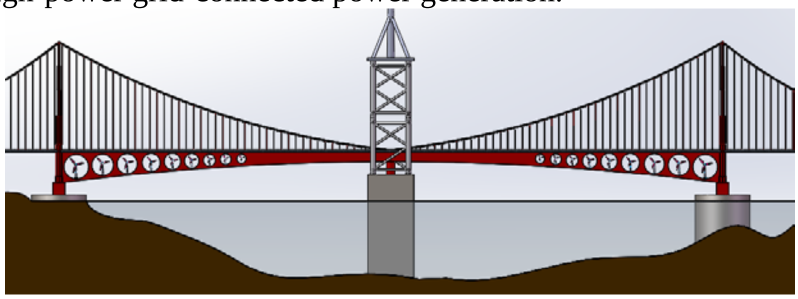


Figure 3 Support structure of the bridge

2.2.3 Design of double rotor wind turbine

As shown in Fig. 4, the power generation part of the dual-rotor wind turbine generator adopts a high-speed shaft, and a low-speed shaft rotates at the same time, and the generator is driven by the same spindle with a bevel gear. All components such as rotors, shafts, and generators are limited to one-piece rotation.[5]

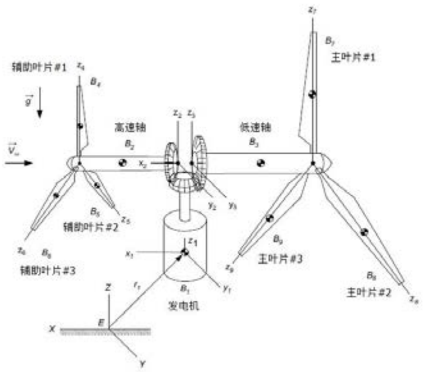
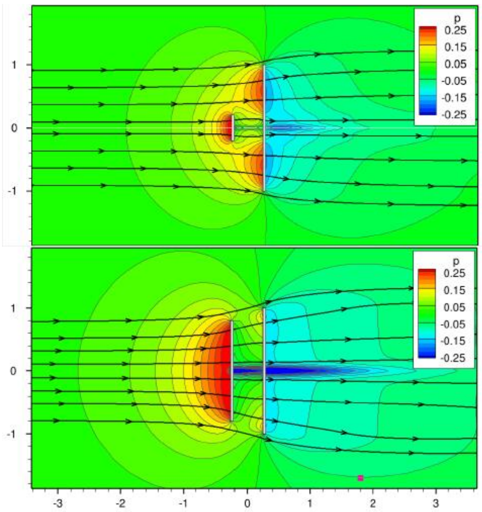


Figure 4 Schematic diagram of dual rotor wind turbine

Next, the ratio of the diameter of the auxiliary rotor to the diameter of the active rotor is studied, as shown in Fig. 5, which is a schematic diagram of the flow and pressure of the dual rotor simulation. From the simulation, we can find that by changing the radial ratio of the different auxiliary wind turbines without changing the axial spacing of the wind turbines, it can be determined from Fig. 6 that the dual rotor wind turbine generator Cp is compared with the single rotor horizontal axis wind turbine generator. The growth is most pronounced when the tip speed ratio is 5-7 and the auxiliary rotor radius ratio is 0.18-0.28.



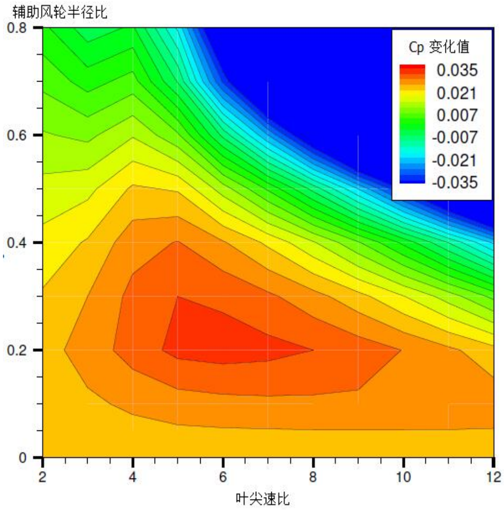
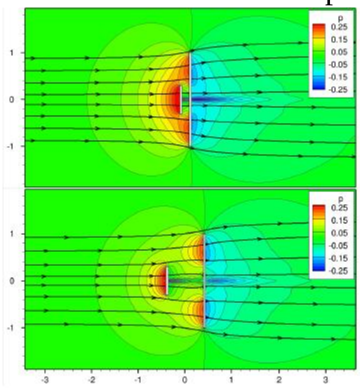


Figure 5 Dual rotor simulation (different sizes) Figure 6 △Cp(DRWT-HAWT)

At the same time, we simulate the analysis by changing the radius of the auxiliary wind wheel and the main wind wheel and changing the distance between the wind wheels. Figures 7 and 8 are schematic diagrams of the flow and pressure of the dual rotor simulation. As can be seen from the figure, compared with the single-rotor wind turbine, when the twin-rotor wind turbine Cp has a tip speed ratio of 5-7 and a wind wheel spacing coefficient of 0.03-0.30, the growth is most significant.



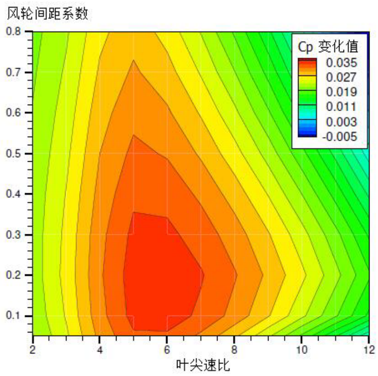


Figure 7 Dual rotor simulation (different spacing) Figure 8 △Cp(DRWT-HAWT)

The simulation study shows that the size of the auxiliary wind wheel should be 25% of the size of the main wind wheel, and the distance between the two wind wheels is set to 0.2 times the radius of the main wind wheel. The Cp increase can be achieved by the concept of DRWT to be approximately 0.035, which increases the aerodynamic efficiency by approximately 7%. This is mainly due to the efficient use of the energy flowing at the main rotor hub, and the other reason is the addition of a wind wheel, which utilizes a portion of the energy.

Combined with the characteristics of the wind turbine built on the bridge, a form of combination of the jacket and the cement foundation is proposed. The double-rotor wind turbine on the bridge is linked to the I-beam concrete structure under the bridge through the jacket, and the top of the jacket is connected to the base section, as shown in Fig. 9. This basic structure effectively disperses the weight on the pier and ensures safety.

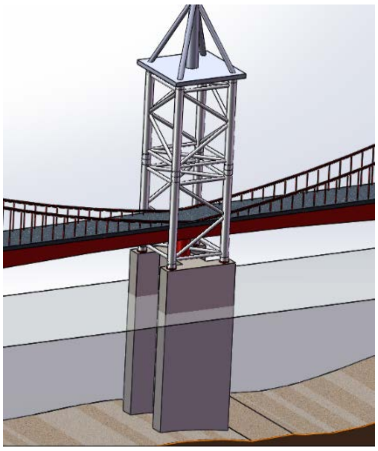


Figure 9 Basic form of dual rotor wind turbine

2.2.4 Wind power generation design under the bridge

For wind turbines under the bridge, small and medium doubly-fed wind turbines with yaw and pitch systems are used. Similarly, the wind turbines under the bridge are also in a row layout, so there is no need to consider the wake effect. Due to the increased weight of several wind turbines under the bridge, the weight of the bridge itself is increased. Therefore, while using the suspension cables on the bridge, the arch structure is also used for support under the bridge.

3. Innovation points

1) Relying on the bridge structure to install wind power generation equipment, the "bridge + wind power" organic combination was constructed. Converting wind energy that could not be used into energy that can be used, and broadening access to energy.

2) Wind power generation equipment is arranged under the bridge and the existing resources are fully utilized.

3) The double-rotor wind turbine is used on the bridge to improve the wind utilization rate and power generation efficiency while preventing the unidirectional stress on the bridge and slowing the fatigue damage of the bridge.

4) Small wind power generation equipment is arranged under the bridge, which can prepare for the development of wireless charging of electric vehicles in the future while generating electric energy, and conform to the development trend of clean energy.

5) Adding a fixed support structure to the bridge while installing wind power generation equipment, strengthening the stability of the bridge and ensuring the safety of the bridge.

4. Application prospect analysis

Above the bridge deck, the dual-rotor wind turbine is integrated into the bridge support structure, which not only prevents the bridge from being fixed in one direction, but also reduces the fatigue damage of the bridge. Moreover, it is effective to use the excellent wind resources that are idle to generate electricity, and to expand the installation and construction area of the wind turbine. The air above the bridge deck is affected by the narrow tube effect, the wind speed is large and relatively sTable, the high-speed wind has a high frequency and the wind resources are excellent; the wind generator is built here, which can make full use of the wind resources and has high power generation efficiency.

At present, China's largest demand for power resources is in the southeastern region. There is a long-term problem of insufficient power supply in the southeast region. There are many rivers in the southeast region, and there are many bridges. The wind power bridges have been rebuilt in the southeast region, which has increased the source of power supply and improved the integration of wind power. The capacity will effectively alleviate the shortage of long-term power supply in the southeast region, reduce the power transmission project to the west, and reduce the cost of electricity in the southeast region. This design expands the application scope of wind power, improves the utilization efficiency of resources, helps wind power generation more fully replace traditional power generation, better reduces pollution emissions, saves fossil energy, has broad application prospect, and provides a new direction for wind power construction in the future.

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