Innovative Design about Offshore Wind Power Resists the Typhoon

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Abstract:

The paper introduces the history, status quo of offshore wind and the resistance to the typhoon problem, put forward the innovation of the resistance to the typhoon design thought and main key components, this paper introduces the key components against typhoon design of main power slip ring, blade, resistance to the typhoon at sea buoy design, etc., and around these key technologies, modeling, calculation analysis was carried out on the related technology, expounds the principle, method and application prospect, for offshore wind improving typhoon resistance, lower manufacture, installation, maintenance and provides some references.

1. The development prospects of wind power industry.

1.1 The development of offshore wind

The quickening pace of global economic development, energy problem has become a worldwide problem. Explore and develop new energy has become a world research for experts in some fields. The development and utilization of the offshore wind power has caught more and more attention. The main advantages of the offshore wind power are as follows:

(1) Save the land resources and reduce noise and the public visual impact;

(2) Large continuous sea area is available that means unlimited development space;

(3) Wind speed is higher than on the land, the wind energy resource is bigger than onshore. 10 km offshore wind speed is usually about 25% higher than the coastal land and the farther the distance from the coast the greater the capacity can be increased significantly;

(4) The turbulence intensity is low; sea level friction force is small. Help to reduce the fatigue load acting on wind turbines; prolong service life to 50 years;

(5) The change of wind speed with height is small that means a high tower does not needed. Reduce the cost of wind turbines.

Offshore wind on the current international development projects mostly in Denmark, Germany, the Netherlands, and the UK, Sweden, Ireland and other European developed countries.

Large offshore wind farms have been set up in Sweden, Britain and the Netherlands, Belgium, Ireland, the United States also has designed for offshore wind power. The world's best wind power industry lies in Denmark, since 1991, after the completion of the first offshore wind farm, and five consecutive built in 2002, and 2003 in Nysted built the world's largest offshore wind farm, the installed capacity of 165 megawatts. According to the report, in the Danish capital Copenhagen, wind power has been able to meet the 85000 people living. China is the second energy producer and consumer in the world nowadays. With the strategic adjustment of China's economic structure, energy problem becomes increasingly prominent. The large-scale development of wind power can effectively reduce the use of fossil energy and reduce greenhouse gas emissions, protect the environment. Chinese government attaches great importance to the wind power construction. China has a long coastline and rich offshore wind resources to support and promote the use of offshore wind power, not only can produce considerable social benefits and economic benefits, but also conforms to China's sustainable development and conservation priority strategy, and also actively support China's industrial structure adjustment.

1.2 The challenge of the fan

Offshore wind power is a hotspot of current international clean energy development. However, the typhoon in the coastal zone is inevitable nature of the challenge; the fan's unique structure makes it very easy to be damaged in the typhoon. The consequence is very serious, not only can't use the typhoon huge energy, but causes huge economic losses. The following is the typical fan damaged by typhoon affected images; costly fan and so became a pile of waste.

Figure 1 failure mode after the typhoon

But not all wind turbines in the face of typhoon is helpless, see an instance below:

Rammasun typhoon situated on July 18, 2014 landed in Guangdong Zhanjiang Xuwen. The typhoon strengthened two consecutive times. The highest level wind 17 (more than 60 m/s) Yuedian Yangqian and Warrior just lies in the main area of typhoon, the former took some measures actively, the entire area has survived the test of the typhoon wind field while the latter did not, the wind field was almost blown over. According to statistics, 13 fans poured out, five turbines were completely damaged (bursting leaves, generator falling, engine room being revealed) so that wouldn't work again. The investment was about 500 million while the loss of more than 200 million.

From the example we can find that, although the typhoon is powerful, as long as the in-depth study, we can also improve the survivability of wind turbine in the typhoon.

Existing measures to resist the typhoon, one of the commonly used method is the strengthening component bearing capacity, such as basic tower strengthening, strengthening of blade and main shaft brake torque and the strengthening of yaw brake torque; Another method is to adopt active protection measures, such as spindle brake braking, wheel track yaw main wind direction, or make the impeller to stop working. Parts bearing strengthen measures are required to enhance blade stiffness of the structure and the main shaft torque, it requires to further improve the mechanical properties of fan unit, will cause the structure design when the load increases, the quality also will further lead to the rising cost of manufacturing, transportation and installation and other related. Drive shaft mechanical braking can brake to reduce the damage of the typhoon, but brake state makes the transmission torque of gear under the changing load, may result in the transmission gear fatigue fracture etc. And the typhoon comes, the wind Ye Shun oar or yaw blade for 90 degrees to have a certain protective effect, but meet the failure such as standby power, limited in the actual effectiveness. Another way of thinking is the typhoon will be huge blades is removed, between time, cost, are not allowed. Based on the present situation, we put our innovative design thinking.

2. The innovative design against typhoon.

Strengthen the structure of wind turbines blindly to improve the ability to resist the typhoon leads to the high cost of blades and finally restricts the rapid development of wind power. This is what has done to the traditional wind turbines. Therefore we start exploring new ideas and finding new methods to help offshore wind turbine resist typhoon.

According to the analysis of those damages of wind turbines that poorly hadn't survived in the typhoon, we have found that the blades damage come the first and most the broken roots of blades.

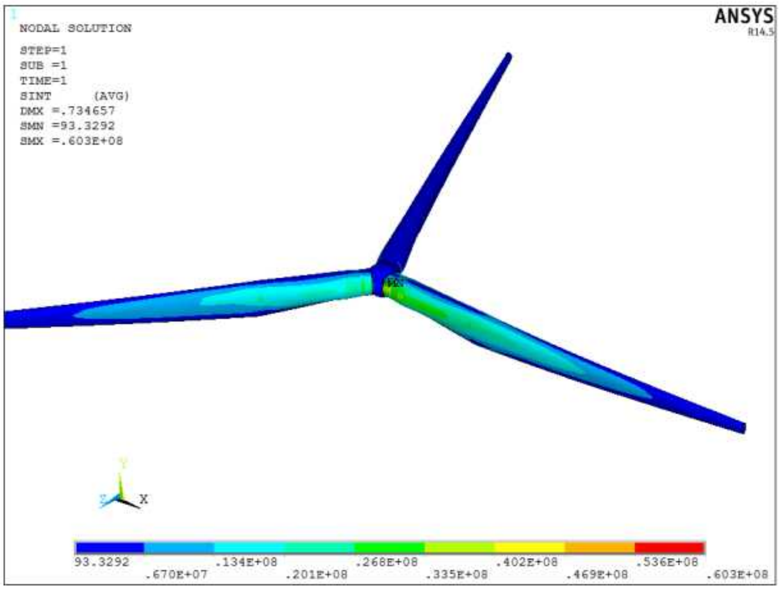

Figure 2 Finite element analysis of stress diagram

We can easily find that blade is connected to the hub that leads to stress concentration just like the structure of cantilever beam. The blade begins to break from the root system where stress concentrated most in the strong wind. Cantilever beam structure is so common in our daily life that we have found they adapted a same way. Life is always the best teacher, these things such as bridge tower of the bridge, construction cranes, and telephone poles give us inspirations. We find that all these unanimously adopted a way that can effectively decrease the stress concentration problem through suspension cables. We put forward our own solution along this thinking: Three blades are connected by wire, using the special device to ensure the completion of action such as pitch movement.

Assuming the blade in the feathering state, in the normal state against typhoon work, blade at least windward side, nature can withstand typhoons one's deceased father grind. Extreme cases is the direction of the wind changes suddenly, share to attack leaves from left to right direction. In order to simplify the analysis, assuming rigid blade, the vertical upward blade by horizontal force for F. Into 120 degrees with the other two blades, halve the windward area of the projection, decomposition to the vertical direction of blade force component are1/2 F, install them on blade shaft bending moment just cancel each other out, natural drainage has the effect of the typhoon. This kind of thinking about dispersion and the combination is just the same as the Chinese old saying" A fence three piles, three to help a hero"

Wire rope has many advantages such as low cost, tensile performance. Most important is that it can effectively reduce the intensity of the blade that has been required before. Schematic diagram is as follows:

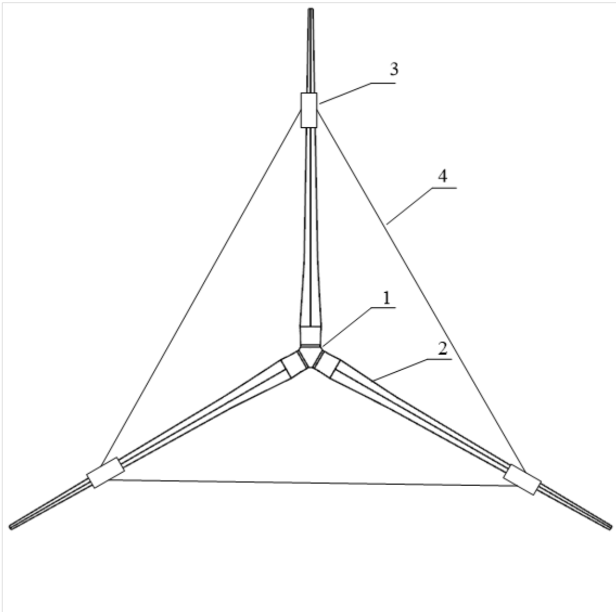

Figure 3 Structure

Cables are joined at two-thirds of the blade root .From the structure of modified modeling, finite element analysis results as shown in the figure below:

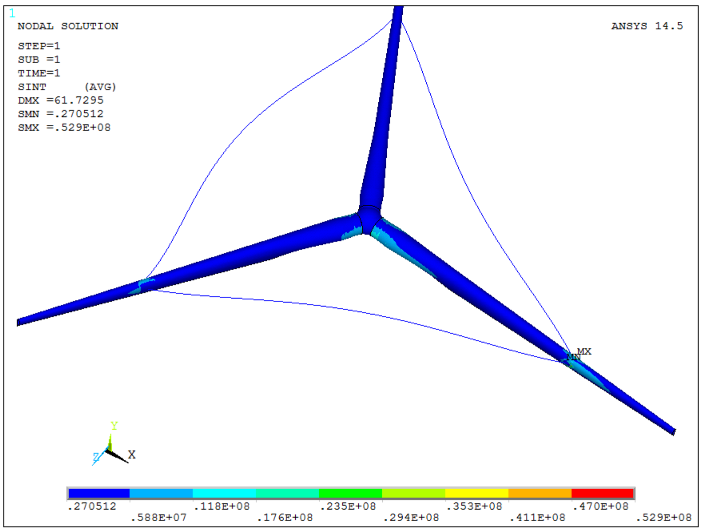

Figure 4 Modified finite element stress diagram

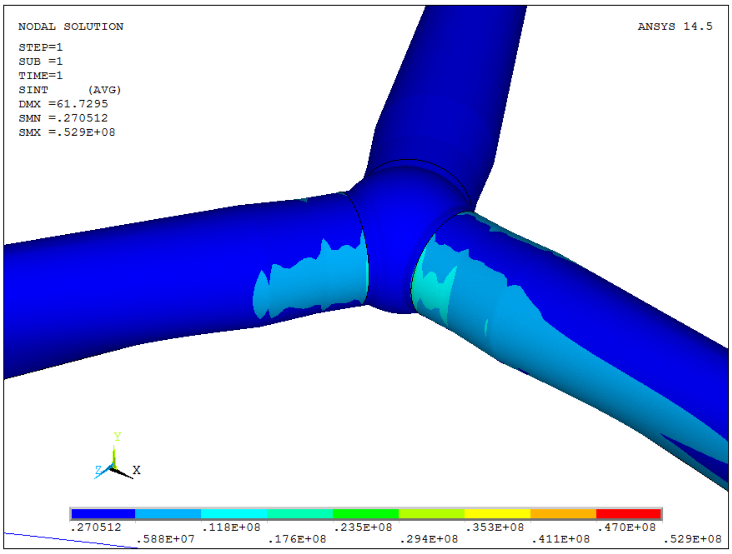

Figure 5

As you can see the original area of stress concentration, after strengthening, in such a way that improved greatly. In this way, we have calculated that the stress of the blade will have decreased by 66.8% and 56.2% for strain when the wind speed is 60m/s. That means these offshore wind turbines will resist Beaufort scale 17 typhoons. In addition, the cost of this device is only 5‰ of the whole wind turbines. At the same time, it shall not affect the feathering and pitch. This effectively reduces the manufacturing costs and enhances the capability against typhoon.

3. Wind turbine yaw system to improve the design

We can use the phrase "a cable bolt on the wind", to summarizes the key components of the fan system, yaw unmoor limits the development of wind power system. So you can through the optimization of some key parts design, improve the fan running stability of the whole, so as to improve its ability to survive in the typhoon, and effectively reduce the cost.

The marine generators set have a yaw system. The main function of a yaw system is adjusting the direction of the wind rotor in accordance with the wind direction. By keeping the rotor windward, we can make full use of wind power and improve generating efficiency. But owing to the changeability and instability of the wind direction, the nacelle has to yaw constantly to adjust the direction of the wind rotor. Then, chances are that there will be continuous deflection for the wind turbine in the same direction. If it happens, the cable will be broke when twining; the consequences and loss of that are incalculable. Yaw systems, when the twine times doesn't reach the utmost limit of twisting circle---say 4 laps, do untwist the cable automatically on condition that the wind turbines are off, which affects the efficiency of generating. Manual operation is needed either because of malfunction of the turbine or the utmost of twine, which threatens the safety of the staff and increases expense.

The structure of a traditional yaw system is as shown below.

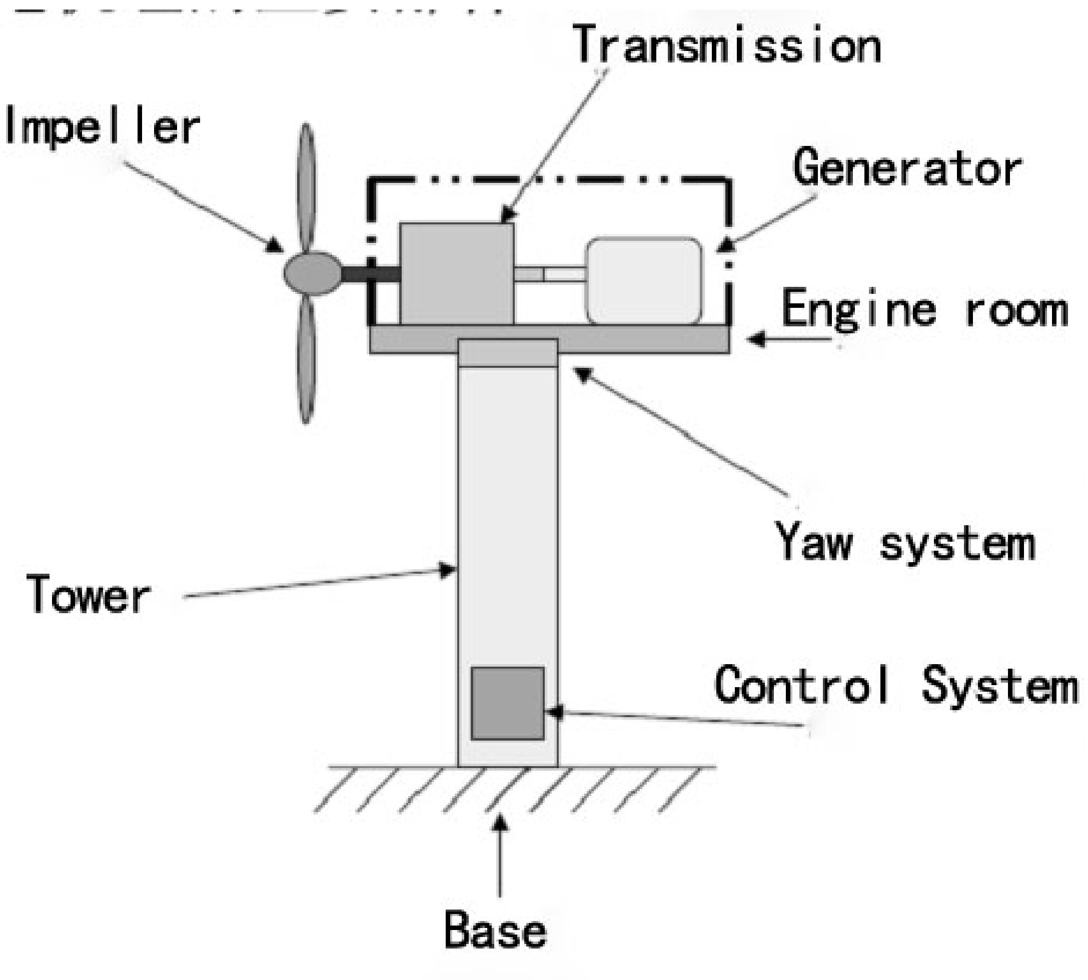

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Figure 6 Yaw structure diagram

On account of the problems brought by the traditional untwisting system, we propose to apply the main power slip ring in place of the untwisting system to simplify the generating mode.

The structure of a main power slip ring is as shown below.

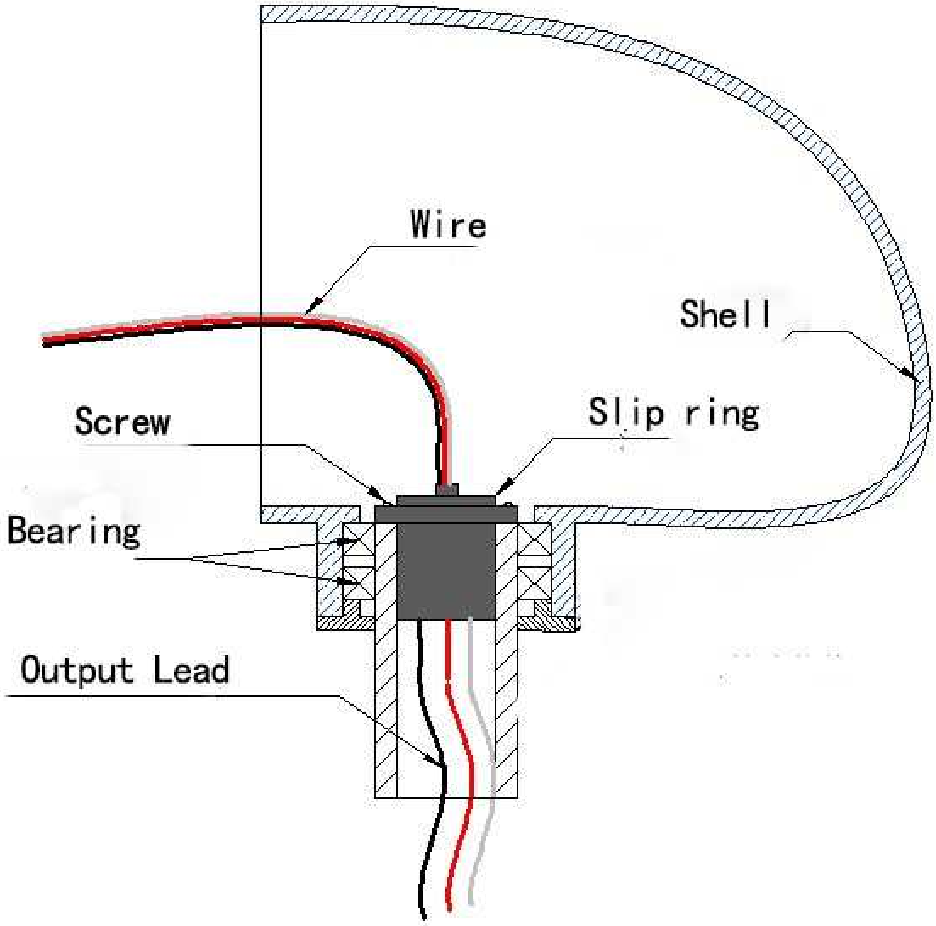


Figure 7 the main power slip ring installation schematic diagram

By applying the main power slip ring, the number of yawing circles is no longer limited, and the problems raised by traditional untwisting systems we mentioned above will vanish. Meanwhile, the normal transmission of generating power will be guaranteed. Also, applying the new system can cut down the cost by saving up the expense of cable usage. (Currently being developed)

4. Fan lifting design of buoy

Wind farm construction is a complicated system engineering, sea installed cost is extremely high, including installation and maintenance costs accounted for as high as 40%.

Many sea fan installation of specific methods, the goal is consistent, namely in the appropriate input reduce offshore operation time saving the total cost as far as possible, and to avoid delays. Can be classified into the installation methods can be divided into three kinds:

①The first for the traditional hoisting method, project is divided into three steps, namely

(1) The installation of the fan base;

(2) Fan tower installation;

(3) The upper fan facilities installation, including cabin and blade.

②The second improved method, proposed to include the fan tower fan as a whole and the entire upper facilities in advance on shore installation and debugging, and then shipped to site for installation as a whole.

③Third overall method, envision the fan and fan as a whole, the basis of using basic buoyancy by barge traction to wind power site, finally by loading ballast installed directly in the bottom of the sea.

These methods have their own advantages and disadvantages; the most widely used traditional hoisting method is still the first one. However, no matter use what method, are inevitably bringing the installation of expensive cost, based on this, we design a new type of fan, suspension tower drum fan.

Using common East Steam 1.5 MW wind turbines to do simulation calculation, East Steam specific parameters of the 1.5 MW wind turbines are as follows:

Figure 8

• engine room		56,000
• Wind wheel		about 32,000 (FD70A)
		about 35,000 (FD77A)
• vane		5,393 (34m)
		6,285 (37.3m)
• Gearbox		16,000
• Generator		6,800
• Hub		16,000
• Spindle		7,150
• Tower	height of Wheel 61.5mm	90,400
	height of Wheel 65mm	100,400
	height of Wheel 90mm	174,000
	height of Wheel 100mm	263,500

Figure 9

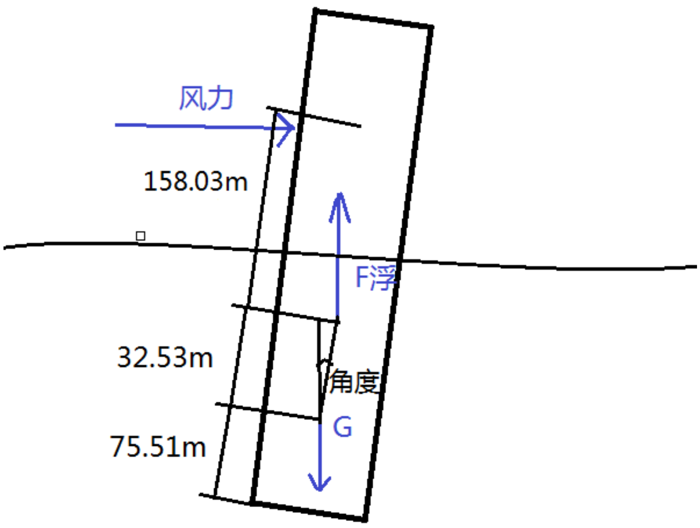
Suppose internal diameter of the same as the fan at the bottom of the buoy is 4 m, 40 mm the thickness of the wall, height of tumbler design of bearing block is x, in order to ensure it swings not as so obviously, the height of the section which exposed to the air is 200 m;

Consider that the fan can dive like a submarine when the typhoon comes. Leave the head of the generator on the surface of the water when the typhoon comes. And remain around 10 m high cushion to resist the hurricane.

Based on Centroid Theorem that position of mass center can be more than 75.51m above the bottom and buoyancy point away from the bottom of 108.04 m, centre of gravity is lower than the buoyancy point, according to the principle of "tumbler", the design has good stability.

About the pendulum Angle calculation is as follows:

Check information available, the power that 40 m/s wind gives to the fan is about 825.6 KN, the force created by the fan and buoy the overall equivalent to one, the force analysis and the diagram below:



$$\sum M = 0;$$

(1)The moment is zero , the angle can be obtained $\theta = 9.85°$

(2) When the typhoon comes, about 10 m of the fan above the sea, in the same way to get

$\theta' = 1.23°$ .Through calculation and analysis, the fan has a good stable performance

(3) The force of the cable

According to the force balance equation of the horizontal, cable force under on basic is equal to the size of the wind. In the vertical direction, the specific size is relative to the angle between cable and the buoy. Based on the vector triangle rules of force, we can easily get the total force on the wire.

(4) Diving time

3 days before the arrival of typhoon usually can send forecast, so fans have plenty of time to descend, in order to make it more stable go smoothly, we assume that the diving need an hour, an hour and about 1130 cubic meters of water injection (depth of 90 meters), and from the underside of up to 200 meters of location using two inlet (guarantee) the strength of the overall structure, the calculation will be each inlet diameter of 2 m.

(5) The rising time

Suppose also need a hour to 1130 cubic meters of water time, if use four drainage pumps, (each machine shrinks 282.5 cubic meters per hour)

(6) Expected to increase component

Electromagnetic valve, drain pump, heavy capsule

(7) Wind speed of drop ratio

100 meters high wind speed of 70 m/s, according to the wind profile index formula, $v = v_1(\frac{h}{h_1})^n$ the ocean n = 0.1, when fan 10 m after diving in, considering the wind load Angle, for 60 degree Angle, further down by about 50%) get the actual wind speed is about 27.8 m/s, the wind speed to 60.3% decline.

(8) Fan operation

Fan run in the 200 m or so deep, when the typhoon comes sinking, rise when they leave.

Using deep-sea buoy type wind power can significantly reduce the installation cost and operation cost, the utility of the good resistance to the typhoon concurrently at the same time.

5. Conclusion

1. Using blade resistance to the typhoon is expected to strengthen structure can greatly reduce the intensity of blade design allowance, and reduce the installation structure strength matching allowance, and can reduce the corresponding transportation, installation and maintenance cost.

2. Use the main power slip ring structure will replace the yaw unmoor system, reduce the two laps to reserve the direct costs of the cable, at the same time, can change the wind and resistance to the typhoon mode, reduce the failure rate, improve the wind power.

3. Using deep-sea buoy type wind power, can provide a new mode of resistance to the typhoon deep, at the same time, through the rise and fall of buoy, reduce the difficulty of installation and maintenance, lower maintenance costs.

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