Research on Small Wind Power System Based on H-type Vertical Wind Turbine

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Abstract. This article is based on past experience and analysis of the advantages and disadvantages of horizontal and vertical wind turbine, improves blade airfoil structure of the generator, designs a new class of small vertical wind power generation system. The system overcomes the traditional level wind power system starting wind speed, and noise, the influence of wind direction and other shortcomings, starting with a breeze, no noise, reduce resistance from wind impact performance.

Introduction

Wind power has the advantages of no pollution, renewable and low relative cost which makes it coming out on top in the field of new energy. However, with the increasing number of large-scale wind farms, the occupied land is also increasing, social contradictions have become increasingly prominent, how to solve this problem has become the bottleneck of renewable energy and new energy technologies.

The Classification and Comparison of Wind Turbines

Wind turbines is various, but according to the wind wheel rotation axis direction it can be divided into two categories: horizontal axis wind turbines (wind wheel axis of rotation parallel to the wind direction) and the vertical axis wind turbine (wind wheel rotation axis is perpendicular to the ground or air flow direction).

Horizontal Axis Wind Turbine

Horizontal axis wind turbine can be divided into two types of lift and drag type. Lift type wind turbine rotates fast, drag-type rotates low. Blade design of horizontal axis wind turbines is commonly used blade element theory, the main methods are Glauert law, Wilson method and so on. However, blade element theory ignores the flow interference between each blade element and the designs of the blade element theory application have overlooked the airfoil resistance, this design inevitably caused uncertainty outcome.

Vertical Axis Wind Turbine

When the wind changes, vertical axis wind turbine (wind round effect shown in figure 1) does not need to towards the wind, compared with the horizontal axis wind turbine this point is a big advantage, not only its structure designs simple, but also it reduces wind wheel gyroscopic forces towards the wind.
Comparison

In the design aspect, the flow of the vertical axis wind turbine is more complex than the horizontal axis which is typical of large unsteady flow separation, not suitable for using blade element theory to analysis and design. This is an important reason for the vertical axis wind turbine not long-term development. With the continuous development of computer technology, computational fluid dynamics has been great progress, from the initial small disturbance velocity potential equation to Euler equation, as well as more complex N-S equation. The current CFD technology is fully capable of simulating complex flow in complex geometries. For blades of vertical axis wind turbines, we can already use CFD approach to design, which is undoubtedly more accurate than the blade element theory. The blade design of horizontal axis can’t apply CFD approach to design, which is decided by two wind turbine structure. Due to the twist angle of each section, chord length and the tip speed ratio is different, if using CFD to simulate the Blade horizontal axis, you must use three-dimensional model, and the computing grid needs at least 1 million, so that the entire amount of calculation will be greatly increase. Intuitively, simulating a work condition on the PC which uses P4 3.0G CPU. Computing its time takes about one week time, if designing a wind turbine it may take several years to ten years. This cost of the industrial design is difficult to accept. The vertical axis is completely different, each section of the blade is the same, so that we can be simplified into two dimensions, number of grids greatly decreased, the amount of calculation can be decreased, a condition generally simulating only needs four hours.

![Wind Wheel Effect Chart]

Figure 1. Wind Wheel Effect Chart.

By comparison, it is clear to see the design method of vertical axis wind power generation is much more efficient than the horizontal axis wind power, and it has a breeze to start, no noise, reduce resistance from wind influence, etc., this article just designs a new type of wind power generation system by using a vertical axis wind turbine.

The Features of Vertical Axis Wind Turbine Structural

Types vertical axis wind turbine has a lot, and because the wind turbines will be converted to the machine’s major components can be rotated by the wind action of the wind wheel, whereby the structural vertical axis wind turbine structure is mostly in the form of wind turbines are classified, the main models S type, H-type and rotary type, advantages and disadvantages of each model are as follows:

(1) S type (two semi-cylindrical blade axes staggered)
Advantages: a greater starting torque.
Cons: easy to produce asymmetric airflow side thrust, tip speed ratio less than 1, does not apply to small wind turbine.

(2) Φ-type (using Troposkien curved blade)
Advantages: the blade is not subjected to bending stress, light, has a higher tip speed ratio.
Cons: inconvenient using pitch moments and auto-start technology.

(3) H-type (with rail and cable support straight blade)
Advantages: Variable pitch moment, wind can sweep a large area, suit for small wind turbines.
Cons: low tip speed ratio.

(4) Rotary Wing (straight blades which can automatically adjust the blade angle of attack depending on the speed)
Advantages: constant speed, can adapt to changes in wind speed, can be realized from the start.
Cons: pitch mechanism complicated, not suit for small wind turbine.

As existing design conditions, we need to design a structure which is small, variable pitch moment for a variety of wind, S-type and rotary type does not apply to small wind turbine, and Φ-type can not use pitch moment and auto-start technology, so the choice of this article is H-type vertical wind turbine. This article improves the impeller so that it is similar to an airplane wing, the breeze started up, variable pulp moment, swept large area, and reduce the role of the resistance.

The Wind Turbine Aerodynamic Characteristics

Wind turbine uses aerodynamic principle, similar to an airplane wing, the wind does not push motion of the blades, but blow the blade which forms blade positive and negative pressure, this pressure would generate lift or drag, so that the impeller rotating constantly cross Merry which generates a rotating kinetic energy.

Known by the fluid mechanics, the kinetic energy of the gas stream is $E = \frac{1}{2} \rho S v^2$, $\rho$ is the gas density, $v$ is the gas velocity, $S$ is the cross-sectional area through which gas flows. Since wind speed after passing through wind wheel can not be zero, so the wind can not have the energy to be completely absorbed and used, that can only absorb some of the energy of the wind which becomes the blade mechanical energy.

Then we look at the how the wind wheel takes advantage of much wind? The first wind turbine aerodynamic theory was founded by German Betz in 1926. Betz assumed that the wind wheel is ideal, namely wind turbine no wheels, an infinite number of blades, the air flow through the rotor is no resistance, in addition to assuming the airflow through the whole rotor swept surface is uniform, and the direction of the air flow velocity through wind wind along the front and rear wheels are wheel axis, as shown by the figure 2 of the wind wheel before and after the gas flow.

Figure 2. The Before and After Curve Through the Airflow of Wind Wheel.
Suppose wind speeds of airflow cross-section $S_1$, $S$, $S_2$ respectively are $v_1$, $v_2$, $v_3$, if the air $S_1v_1 = Sv = S_2v_2$ (1)

The force of wind acting on the wind turbine by Euler’s theory is:
$$F = \rho Sv(v_1 - v_2)$$ (2)

The power that the wind turbine absorbs is:
$$P = Fv = \rho Sv^2(v_1 - v_2)$$ (3)

The difference between the kinetic energy of the wind wheel upstream and downstream of the air flow is as follows:
$$\Delta E = \frac{1}{2} \rho Sv(v_1^3 - v_2^3)$$ (4)

Seen by the law of conservation of energy, the power that wind turbine absorbs is equal to the amount of change in the air flow kinetic energy, namely:
$$P = \Delta E$$ (5)

So we can get
$$v = \frac{v_1 + v_2}{2}$$ (6)

The force of wind acting on the wind turbine is:
$$F = \frac{1}{2} \rho S(v_1^2 - v_2^2)$$ (7)

The power that the wind turbine absorbs is:
$$P = \frac{1}{4} \rho S(v_1^2 - v_2^2)(v_1 + v_2)$$ (8)

Deriving $v_2$ of the equations (8) we can obtain:
$$\frac{dP}{dv_2} = \frac{1}{4} \rho S(v_1^2 - v_2^2)(v_1 + v_2)$$ (9)

Order $\frac{dP}{dv_2} = 0$ of equations (9) has two solutions, solution 1 $v_2 = -v_1$ (this solution meaningless, rounding); solution2 is $v_2 = \frac{v_1}{3}$, and then, $P$ is the maximum, put it into the equations (8) is:
$$P_{\text{max}} = \frac{8}{27} \rho Sv_1^3$$ (10)

The maximum efficiency by Fan theory:
$$\eta_{\text{max}} = \frac{P_{\text{max}}}{E} = \frac{8}{27} \rho Sv_1^3 \times \frac{16}{27} = 0.593$$ (11)
Useful power output of the wind turbine that can actually get is \( P = \frac{1}{2} \rho v^3 C_p \), where \( C_p \) is the actual power coefficient of wind turbine, according to the Betz limit theory we can get that \( C_p < 0.593 \), the power loss can be interpreted as part of the stay without leaving the kinetic energy.

The Basic Parameters of the Impeller

Based on the above analysis and calculation, we simulate the various data of airfoil, the results under common airfoil 227 can be obtained as shown in Fig.3 and 4.

![Figure 3. The Actual Shape of the Blade Wing at 3.5 Degrees.](image)

![Figure 4. The Distribution of Cp in Figure 3.5 Degrees](image)

The Output Characteristics of the Wind Turbine

According to the above we can analyze the ideal power output of wind turbine by the aerodynamic characteristics of wind turbine. But in the actual wind power generation system, when the wind starts up, it takes some moments to overcome its internal friction, this moment is called a wind machine starting torque. The starting torque is related with friction of wind turbine transmission mechanism. Therefore the wind turbine has a minimum working wind speed Vmin, only when wind speed is greater than Vmin, the wind turbine starts to work. When the wind speed exceeds a certain value, based on security considerations, the wind turbine should be stopped, so each wind turbine has a predetermined maximum operating wind speed VMAX, this wind speed is related with wind turbine design strength value which is given parameters when it designed. The wind speed between the minimum Vmin and maximum VMAX is working wind speed of wind turbine, corresponding to the power output of working wind turbine, the wind speed when it reaches the output power of working wind turbine is referred to rated wind speed of wind turbine. To take full advantage of wind resources to power, it should determine the starting wind speed and rated wind speed of the wind turbine according to local wind resources, and then select the appropriate model. Power output characteristics of the wind turbine can be shown in figure 5.
Conclusions

This article is based on the theoretical analysis, that compared with the traditional horizontal axis wind turbine, the vertical wind turbine generator has several advantages, such as breeze starting, no noise, reduce resistance from wind influence. This article analyzes the aerodynamic resistance and output power characteristics of wind turbine on the basis of vertical wind turbines, improves blade airfoil structure of the generator, designs a new type of small vertical wind power generation system.

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