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Research on Active Yaw Mechanism of Small Wind Turbines

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Abstract

This paper presents the development process of an active yaw mechanism for small wind turbine with a power of 5kw or more, which contributes to avoid wind turbines turning frequently. In this mechanism, roller bearings make a revolute joint, a DC-motor provides power for yawing and combines a self-locking worm and a reducer to give system a big transmission ratio, which give this mechanism a low yaw angular velocity and make it yaw steady and accurately. This paper is of guiding significant to improve yaw stability and accuracy, extend the working life and enhance the wind power generation efficiency.

Keywords: wind turbine, active yaw, mechanism design;

1. Introduction

Wind as a renewable green energy has gained growing popularity among the international community, and is most likely to become one of the principal sources of global electric power in the near future. In the past 15 years, the global wind power has increased by more than 25%[1]. In these areas such as remote rural areas, pastoral areas, lakes, islands and other places without electric grid, the small wind turbines is good solution. In China, the production of the small and medium wind turbine has increased at a pace of 40% for 3 consecutive years [2]. In recently years, research on small wind turbines has been increasing rapidly. These researches focused mainly on MPPT control and control algorithms [3-6], followed wind turbines controller [7-8]. There is few research on wind turbine structure, for example, papers [9-12] had studied the tail wind device (passive yaw), but currently there is almost no research on active yaw system for small wind turbines. This paper designed an active yaw mechanism to suit small wind turbine.

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2. Traditional small wind turbine

In general, wind turbines with less than 10kw power are called small wind turbines. A Traditional small wind turbine consists of a generator, three blades, an axisymmetric body, a tail wind device, tower and so on (Fig.1).

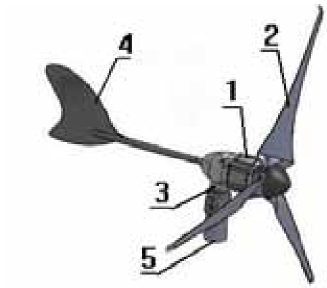

Fig.1. Traditional small wind turbine.

1-Generator, 2-Blade, 3-Axisymmetric body, 4- Tail wind device, 5- Tower

Wind energy is an unstable energy. As wind direction is often changing, horizontal-axis wind turbines need to yaw to get maximum power generate efficiency. Horizontal-axis wind turbines yaw system is divided into two types: passive yaw and active yaw. Passive yaw includes two ways: tail wind device yaw and helm yaw. Among middle and small wind turbines, tail wind device is great widely used. The tail wind device is installed behind wind wheel, use the leeway to product yaw moment and put wind turbine at the windward position. Tail wind devise is a mechanism and free way , its advantages are that structure is very simple and low manufacturing cost； its disadvantages are that uncontrollable、small yaw moment and unstable yaw, all these make wind turbine yaw frequently, reduce the efficiency of power generation ,effect wind turbine service life. Current all modern big wind turbines use active yaw system, which, according to senor signal, adjust wind turbines to the windward position by electric or hydraulic device. Active yaw is a control、electric (hydraulic) way, which is flexibility and controllability, yaw stably and accurately to avoid frequent rotation, reduce the mechanism wear. As the daily electric consumption of user increasing, the market need of kw-class or even 10 kw wind turbines is also on the rise. Power of wind turbines increases, structure becomes complex, components' weight and load increase, the moment of inertia also increases, so it is difficult for wind tail device to generate enough yaw torque to adjust wind turbines in time.

3. Active yaw system principle

According to the principle of aerodynamics, wind turbines absorb power from wind.

$$P=\frac{1}{2}\rho SV^3C_P\cos\theta \qquad (1)$$

Where ρ is air density, S is wind wheel area, V is wind speed, C_P is power coefficient, θ is yaw error. the angle deviation between the wind direction and wind wheel rotation axis is called yaw error θ, Obviously, when θ=0, that is at the windward position ,wind turbine will get maximum power generate efficiency.

Active yaw system is a servo system (Fig.2), yaw controller determine whether yaw or not according to sensor signal, when θ ≠0 or exceeds a certain value, yaw mechanism will get instruction and yaw to put wind turbines at the windward position.

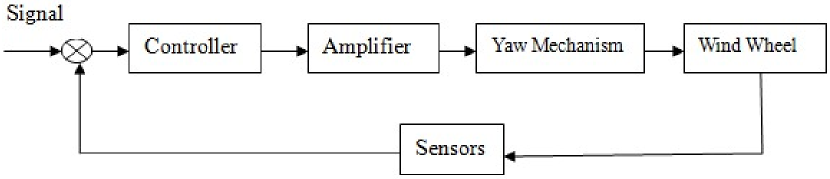

Fig.2. Yaw control system.

4. Active yaw mechanism design

4.1. Overall scheme

The active yaw system for small wind turbines consist of a yaw motor，a reducer，a worm and two yaw bearing. Active yaw mechanism completes yaw motion in accordance with the instructions of yaw controller. Tapered rolling bearing connecting engineroom and tower make a revolution joint (Fig.3). A yaw motor connects to reducer, so movement and force were transmit to worm, worm mesh with worm gear, which connect rigidly to wind tower. Therefore, the active yaw mechanism can drive engineroom with wind wheel to rotate at a certain angular velocity (Fig.4). Because worm gear and reducer are used in this mechanism, first of all ,they can provide with a big ratio to meet the need of system .besides, worm is designed to have a function of self-locking. In this way, wind turbines just can be drive to rotate by the yaw motor. So this design eliminates mechanism of yaw braking to simplify the wind turbines' structure and reduces the cost.

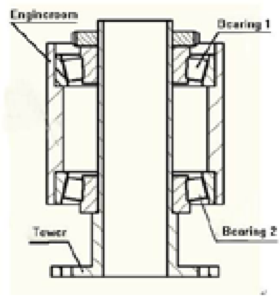

Fig. 3.The installation mode of yaw bearing mechanism

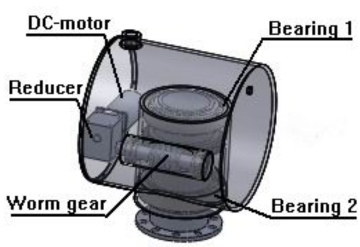

Fig. 4.Design drawing of active yaw

4.2. yaw motor power

Yaw motor should have a proper power so that there is enough yaw torque to conquer resistance moment for yawing. Studies show that when the design of wind turbines is 300kw~3000kw, the power of yaw motor is generally between 1kw~10kw. The power of yaw motor could be calculated by resistance moment. In large wind turbines the resistance moment consists of friction resistance moment, wind resistance moment, inertial resistance moment, damping moment and turbine's torque. Because of the different mechanical structure, in small wind turbines we mainly consider friction resistance moment, wind resistance moment and inertial resistance moment. So the power of yaw motor can be set by following formulas.

$$\mathrm{M} = \frac{9550P}{n_0} i_1 i_2 \qquad (2)$$

$$M \geq \mu(M_F + M_W + M_P) \qquad (3)$$

Where M is yaw torque, P is power of yaw motor, n_0 is speed of yaw motor,i_1 is the transmission ratio of reducer, i_2 is the transmission ratio of worm, η is total transmission efficiency, M_F is friction resistance moment, M_W is wind resistance moment, M_P is inertial resistance moment, μ is safety factor, greater than 1.

4.3. Yaw angular velocity

To reduce the effect of yaw gyroscopic moment on wind turbines' security and life, a proper yaw angular velocity should be selected. According to the actual situation and research, there is a yaw angular velocity recommended values in Table 1.

$$\mathrm{n} = \mathrm{n}_0 / i_1 i_2 \qquad (4)$$

Where n is yaw speed, n_0 is speed of yaw motor, i_1 is the transmission ratio of reducer, i_2 is the transmission ratio of worm.

Table 1. Yaw speed recommended values

Wind turbine power（kw）	Yaw speed (rpm)
100-200	0.3
250-350	0.18
500-700	0.1
800-1000	0.092
1200-1500	0.085

According the design, we manufactured a 5kw prototype of active yaw wind turbine (Fig.4). Parameters are as the following.

P=200w n_0=1800rpm i_1=60 i_2=40 n=0.75rpm=4.5°/s

Fig.4. The prototype of active yaw wind turbine

5. Conclusions

This paper designed an active yaw mechanism for small wind turbines with a power of 5kw or more , which is compact ,not complicated and low cost. The active yaw mechanism prototype combined with a controller had experiments, which show that active yaw mechanism prototype can be fast and flexible responding to instructions of controller and yaw stably and accurately.

In order to improve this active yaw mechanism, further study is required .first, because of the shaking load on roller bearings and low yaw speed, it is difficult for oil film to sustain roller bearing working. So it is a problem that whether grease lubrication could or not support the active yaw mechanism working for a long time. Second, because of the continual changing of wind direction, worm will be impacted by alternating load, gear clearance will increase slowly, and then wind turbines will be given a small jitter when not at yaw. Self-locking function of worm saves a yaw braking mechanism but increases risk of jitter. So the further study of reliable yaw braking mechanism is necessary.

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