

Research on Wind Turbine Overspeed Control through Matching of Rotor and Generator(Oral Presentation)

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ABSTRACT: The reliability and security of small wind turbines is attracting more and more attention with the use of wind turbines on the rise, i.e. the overspeed control in the high winds. The paper proposes an overspeed control method through matching of rotor and generator. The power-rev graph of rotor with different wind speeds is divided into three parts, i.e. upgrade area, peak, downgrade area. The different area presents different matching characteristic of rotor and generator. Two 300W/24V wind turbines are designed and tested, which have different matching characteristics. The theory and experiment both indicate: if a special matching of rotor and generator happens, the wind turbine can complete overspeed control by itself no introducing any more components.

Keywords: wind turbine, overspeed control, matching of rotor and generator

1. INTRODUCTION

The reliability and security of small wind turbines is attracting more and more attention with the use of wind turbines on the rise. One of the reasons cause reliability problems is rotor overspeed in high winds. All wind turbines typically have a means for controlling overspeed. Most small wind turbines furl or fold about a hinge so that the rotor swings toward the tail vane^[1]. These kinds of methods introduce some mechanical components, which easily to be broken.

On the other hand, considering of high costs many advanced control techniques, which have been successfully used on large wind turbines, have not been used on the small wind turbines. And these techniques seems not will be used in future.

This paper tries to develop an easy way to complete overspeed control through the

matching of rotor and generator. Two wind turbines with different matching characteristics were designed with Wilson Method^[2]; here they are called WTG1 and WGT2. The diameter of WTG1 is 1.6m with tip speed ratio 3.5 and diameter of WGT2 is 1.7m with tip speed ratio 4. For comparison, two wind turbines use same airfoil and same type of 600W magneto alternators.

2. THEORETICAL BASIS

The matching of rotor and generator accords with energy conservation completely, that is, input of generator is equal to output of rotor. At same wind speed, the absorption of rotor from wind energy depends on its rotation speed, i.e. if the rotor runs at optimum speed, it will get most energy from wind; if the rotation speed is too higher or too lower, and energy

absorption will be lower. So theoretically we can find some methods to cut down the absorption of rotor to control overspeed.

Within a certain speed, output power of magneto alternator is proportional to its rotation speed. After the wind turbine start-up, the output of rotor increases with its running speed. When the output power of rotor is equal to required power of generator, the rotation speed of wind turbine not increases anymore, between rotor and generator an energy balance reaches. At this time, if wind speed increases (decreases) and the absorption of rotor increases (decreases), the output power of rotor more(less) than required power of generator, then the balance is broken, the rotation speed of wind turbine increases (decreases). On the other hand, if the output power of generator is sensitive to its speed, when the wind speed increases, the rotation speed of rotor not increase because the opposite torque coming from the generator is greater than rotor's torque, then the overspeed will not happen.

After the geometrical parameters of turbine are determined, one of the main factors affect the output of wind turbine is matching of rotor and generator. So traditionally, optimal wind turbine design is the optimum matching of rotor and generator, that is, wind turbine always operates at optimum tip speed ratio.

In this paper, the power-rev curve of wind turbine is divided into three parts, i.e. upgrade area, peak, downgrade area. The peak value is the optimum matching of rotor and generator; at upgrade area, wind turbine operates at a tip speed ratio which lower than optimum value, like WTGa in figure 1; at downgrade area, wind turbine operates at a tip speed ratio which higher than optimum value, like WTGb in figure1. WTGa and WTGb are not traditionally design. But on the other hand, the matching like WTGa has some advantages that the optimum matching don't have. For example, when the wind speed changes from V2 to V4, the rotation speed and the output power of WTGa just

have a little change. So, regarding speed limitation at high winds WTGa is a very good choice.

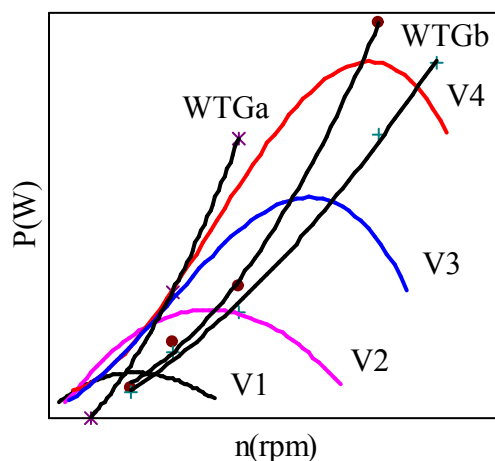


Figure 1: The matching of rotor and generator

3. ELECTRIC POWER TESTING OF MAGNETO ALTERNATOR

For wind turbines which used to charge for battery, generally charging voltage should not be higher than 28V. Considering the wire loss and inverter efficiency, output voltage(DC) of generator is about 26~30V.

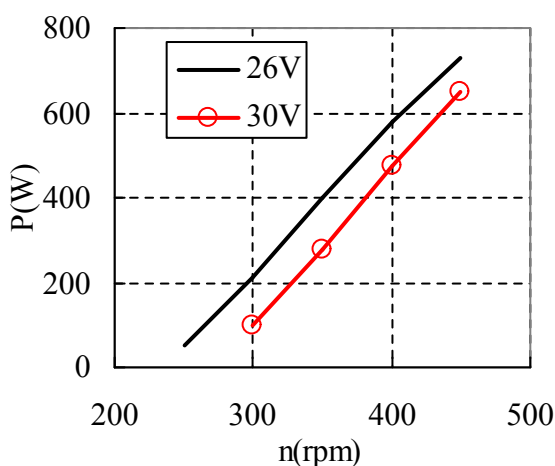


Figure 2: The power-rev curves of 600W magneto alternator with different output voltages

So we need to test the electric power of generator with voltage varies from 26V to

30V. Curves in figure 2 show the sensitivity to voltage of electric power. A rheostat and two batteries (100Ah/24V) is used in experiment to make the output voltage unchanged with rotation speed of generator.

4. TESTING OF THE PERFORMANCE OF ROTOR

The performance of rotor says how output torque and power of rotor varies with rotation speed (rev) with different wind speeds^[2]. The performance of rotor depends on its diameter and geometry of blades. Figure 3 demonstrates the rotors' power-rev curves of WTG1 and WTG2. As shown, the slopes of power-rev curves of WTG2 is larger than that of WTG1, that means rotor's output of WTG1 is sensitive to its rev.

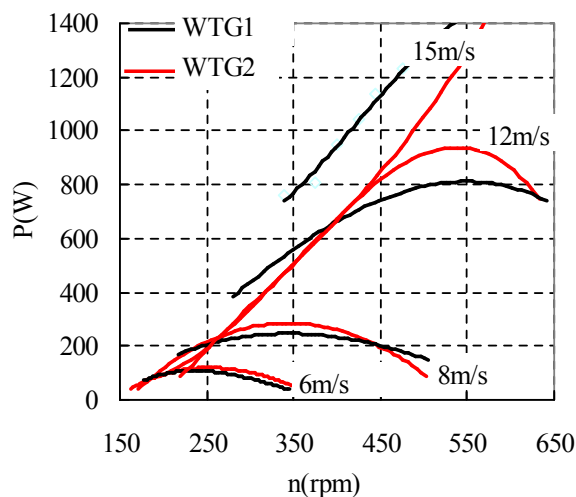


Figure 3: Rotors' power-rev curves of WTG1 and WTG2 at different wind speeds

5. MATCHING OF TURBINE AND GENERATOR

The matching of rotor and generator is very important in the design project. If a bad matching happens, the efficiency of wind turbine will be very lower. Put the output power-rev curves of rotor at different wind

speeds and input power-rev curves of generator at different voltages in the same figure we can get the matching curves of rotor and generator.

Figure 4 shows the matching of rotor and generator for WTG1 and WTG2. As we can see, when the wind speed is 6m/s or 8m/s, rotors and generators almost reach optimum matching for WTG1 and WTG2. When the wind speed is 12m/s, WTG1 and WTG2 are similar in the output power. However at 15m/s the output of WTG2 is much higher than that of WTG1. The most exciting characteristic is that the outputs of WTG2 at 12m/s and 15m/s are almost same. This means that WTG1 has overspeed control ability within a certain wind speed.

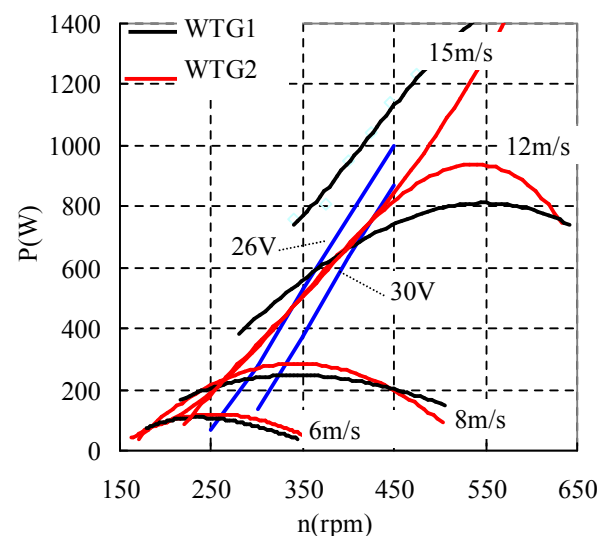


Figure 4: Matching of rotor and generator for WTG1 and WTG2.

6. COMPARATION OF OUTPUT POWER OF TWO WIND TURBINES

Fig 5 shows the electric power output of two wind turbines with 24V battery as loads. For the electric power of generator is sensitive to output voltage, we control the charging voltage in the range of 26V~28V. As shown, when the wind speed is lower than 10m/s, the electric power of two wind turbines is almost same at the same wind speed. However if the wind speed is higher

than 12m/s, the electric power of WTG1 still varies with wind speed, but for WTG2 output power is almost remain unchanged. The results of testing and theoretical analysis reach agreement.

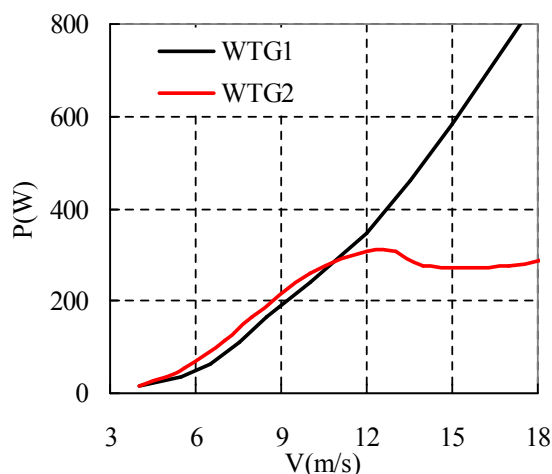


Fig 5: Comparison of electric powers of WTG1 and WTG2

5. CONCLUSION

The paper analyses the different matching characteristics of rotor and generator. And the possibility to control overspeed in high winds through special matching characteristic is testified by theory and experiment. In conclusion, the wind turbines with the following characteristics can control overspeed by itself.

(1) For generator, the power- ω curve should have larger slope when the rotation speed is higher than rated value; furthermore, the matching characteristic of rotor and generator is sensitive to the output of generator. So the output voltage of generator should be limited when making use of the matching characteristic to control overspeed.

(2) For rotor, the slope of power- ω curves also should be larger especially when it runs at lower tip speed ratio.

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