

# The Research on the Braking System of the Small Danielle Wind Generators

Na LI<sup>1</sup>, Xiaoliang WANG<sup>2</sup>, Zhenhua ZHU<sup>1</sup>, Ying LIN<sup>1</sup> and Jie HUI<sup>2</sup>

<sup>1</sup> State Grid Shandong Electric Power Research Institute Jinan, China;

<sup>2</sup> State Grid Shandong Electric Power Maintenance Company

273580859@qq.com

**Abstract.** By researching on the mathematical model of small danielle wind generators, it is easily to find that reasonable load connection and disconnection or changing the load characteristics could control the rotational speed and output power of wind generators. Using the controlling strategy combined with switching braking resistor and three-phase short-circuit braking, the rotational speed of wind generator could be controlled accurately in the scenes of sustainable strong wind or the wind speed continuously increasing. At the same time, users' cost could be ensured. A lot of field experiments had proved the feasibility and practicality of the controlling strategy. The research of this paper would promote the application of small danielle wind generators.

## 1. Introduction

Along with the economic development and environment deterioration, the energy problem has become a problem urgent to be solved. Developing environment friendly and increasing the utilization of renewable energy had become increasingly important subject.

Wind energy was a typical renewable energy with large content, which had been paid more attention for generating. The wind energy was 10 times of the hydropower in the world and the wind energy distributed in almost all the countries and regions. The energy which wind energy could be transformed into power was 53 billion kW•h[1]. As the important part of wind generating system, small wind generators had the advantages of low cost, little environmental influence and convenient installation. Because of the complex topography, large population and residential dispersion in our country, the traditional power grid could not supply power to special areas. Developing small wind generating system could make up the defects of traditional grid[2]. Although the small wind generating technology had a lot of advancement, the safety protection problem under large wind speed scene had not been solved. So the small wind generating and its' grid-connected technology should be improved furthermore.

Danielle wind generators had the characteristics such as simple structure, high tip-speed ratio, and high utilization coefficient of wind energy. Danielle wind generators usually used fixed pitch generating model[3-4]. Restricted by the volume, mechanical structure and cost, general mechanical braking structure could not apply to the danielle wind generators. It was important for reliability operation of the danielle wind generating system to research unloading equipment to control the rotational speed under large wind speed. This paper established the mathematical model of danielle wind generators and provided the controlling strategy combined with switching braking resistor and three-phase short-circuit braking. A lot of field experiments verified that the controlling strategy could

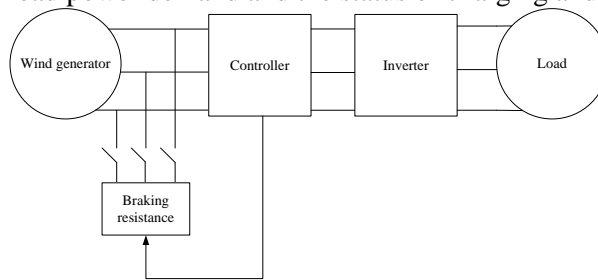


accurately control the rotational speed of wind generator, which had feasibility and practicality for engineering application. The research of this paper could apply for small wind generators controlling to improve operating reliability.

## 2. Mathematical model

### 2.1 The typical power supply system of danielle wind generators

The small danielle wind generators usually used in off-network scenes and could supply power to loads directly. The typical power supply model of danielle wind generators was composed by wind generator, controller, inverter and load. The model of the system was shown as figure 1. The controller was the key part of the system. The controller could do MTTP controlling strategy, battery controlling strategy and switching controlling strategy of braking resistor considering comprehensively by the output of wind generator, load power demand and the status of charging and discharging for battery.



**Figure 1.** The typical power supply model of danielle wind generators

### 2.2 Mathematical model

The energy for danielle wind generator accepted by wind could be expressed as formula (1).

$$P_{in} = \frac{1}{2} \rho A V^3 \quad (1)$$

In formula (1),  $\rho$  -the air density;

$A$  -the sweeping wind area of the wind generator;

$V$  -the wind speed.

The output power of danielle wind generators could expressed as formula (2).

$$P_{out} = C_p \cdot \frac{1}{2} \rho A V^3 \quad (2)$$

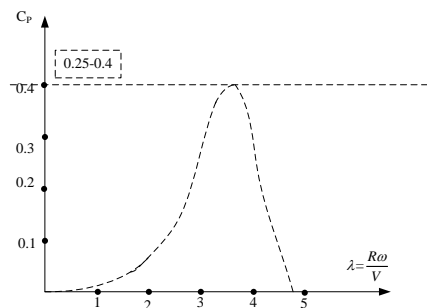
In formula (2),  $C_p$  meant the utilization coefficient of wind energy.  $C_p$  was related to the function of velocity ratio.

$$\lambda = \frac{R\omega}{V} \quad (3)$$

$R$  - radius of the wind generator;

$\omega$  - angular velocity of wind generator.

$C_p$  would change when  $\lambda$  changed. The relationship of  $C_p$  and  $\lambda$  was showed as figure2.  $C_p$  would increase firstly and then decrease along with  $\lambda$  increasing and the maximum was close to 0.4.



**Figure 2.** The relationship between  $C_p$  and  $\lambda$

According to formula (1) and (2), the output power of danielle wind generators was effected by  $C_p$ . According to formula (3), reasonable switching loads or changing the load characteristics could control  $C_p$  accurately and control the output power of the wind generators. So, switching braking resistance could control the rotational speed and output power of wind generators.

### 3. The design of controlling strategy

Literature [5] provided to control the rotational speed of wind generators using braking resistance. The braking resistance could be adjusted according to the detection result of wind speed so as to control the rotational speed of wind generator. Literature [6] provided that although the small wind generators could not use variable propeller pitch control, it was feasible to improve the fault ride-through capability by serial braking resistance. A lot of field experiments had shown that when encountering large wind or wind speed sustainable increasing during braking procedure, the small danielle wind generators could not realize expected braking effect only using switching braking resistance to control wind generator rotational speed. The related parameters of this braking strategy were shown as table 1.

**Table 1.** The related parameters of small danielle wind generating braking system

parameters	number
Rated power	300W
Starting wind	2m/s
Rated wind	9-11m/s
Braking Rotational speed	600r/min

The braking resistance used the three-phase Y connection mode and every phase resistance was  $1\Omega$  and had  $100\Omega$  cement resistance.

In the process of experiments, when the rotational speed of wind generators reached 600r/min, put the braking resistance into operation and sustainable increasing wind speed. The detection results of the wind generators rotational speed and voltage and current were shown as table 2.

**Table 2.** The test results of braking process

Wind speed(m/s)	Rotational speed(r)	Line voltage(v)	Phase current(A)
11.40	596	24.5	10
11.40	0	0.01	0.2
12.87	0	1.8	0.96
14.69	88	2.85	1.73

16.90	139	4.5	2.75
18.85	186	6	3.7
19.89	210	6.7	4
21.32	252	8.12	4.85
22.10	360	11.85	6.7
23.14	405	13	7.22

According to table 2, when the rotational speed reached 600r/min, the controller got into controlling state and switched the braking resistance. At this time, the rotational speed of wind generators would decrease rapidly. But, when the wind speed continued to increase or the wind speed reached over 23.14m/s, the rotational speed of wind generators could not be controlled as expected. So the simple controlling strategy only by switching braking resistance could not control the rotational speed of wind generator accurately.

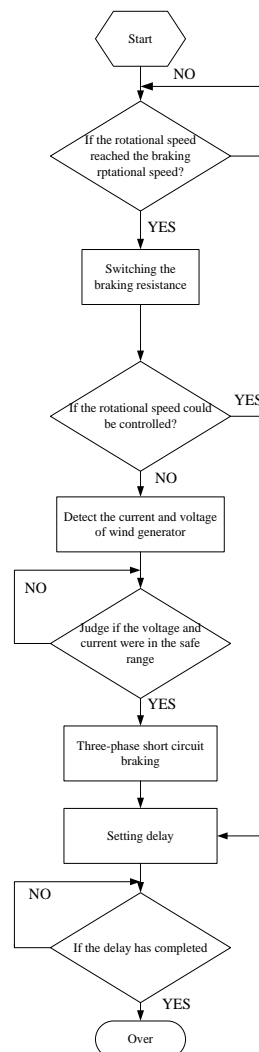
Literature [7] and [8] had provided to use NTC resistance to be braking resistance. By the heat detection produced in the braking process, it was easily to adjust the resistance size. The controlling strategy could reduce the controlling difficulty and could realize three-phase short circuit braking when the heat produced was more than heat output. In the state the rotational speed of wind generators could be controlled accurately. The use of NTC would be restricted by the environment and its' using frequency was about 700. In the regions where wind energy was rich, frequent braking control would endanger the safety operation of wind generator. In addition, the NTC cost of large power was high and this method could not satisfy the economic demand of small danielle wind generators.

By theory research and a lot of field experiments, this paper provided an improved braking control strategy. The flow chart was shown as figure 3.

From figure 3 we could know the whole controlling process. When the rotational speed reached the braking rotational speed, the braking resistance could be switched into automatically. At the same time, in this status:

(1) If the wind speed could not increase continuously, the rotational speed could be controlled only by switching braking resistance.

(2) If the rotational speed of wind generator would continue to increase after switching the braking resistance, the second braking step could be carried out. When the voltage and current were in safe range, use three-phase short circuit braking to control the rotational speed.



**Figure 3.** The flow chart of the controlling strategy

The reasonable delay was set in the above two situations. When the wind speed reached safe speed, the brake control could be relieved and the whole braking process was completed. The controlling strategy provided by this paper avoided the braking failure caused by large wind speed or burned out the wind generators caused by short circuit current.

#### 4. Test results

According to the power supply model of danielle wind generator and the improved controlling strategy, a lot of field tests had done to verify the feasibility and accuracy of the controlling strategy. The test results were shown as table 3.

**Table 3.** The test results of the improved controlling strategy

Wind speed (m/s)	Rotational speed (r)	Line voltage (v)	Phase current (A)
11.25	589	24.4	10
11.25	0	0.01	0.2
12.87	0	1.8	0.96
14.69	88.5	2.85	1.73
14.69	0	0.01	0.2

19.89	0	0.01	0.2
21.32	0	0.02	0.2
23.40	0	0.02	0.2

According to the test results, when the rotational speed reached 600r/min, the controller got into controlling state and switched the braking resistance. At this time, the rotational speed of wind generator would decrease rapidly. The wind speed continued to increase and the rotational speed of wind generators could not be controlled by braking resistance. When the phase current of wind generator reached close to 1.5A, use the three-phase short circuit braking method. As table 3 showed, test results showed that when the wind speed was 14.69m/s, the three-phase short circuit braking method was put into use. Compared with table 2, in the process of wind speed increasing continuously, the improved controlling strategy had better controlling effect and the wind generators could be controlled precisely.

## 5. Conclusion

This paper used unloading brake method to realize the rotational speed control of small danielle wind generators. The rotational speed could be controlled precisely in the status of wind speed increasing continuously and ensured the economic request of users. Field tests had verified the feasibility and accuracy of the improved controlling strategy. The research had high practical value.

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