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Development of Vertical Axis Type Micro Wind Turbine System

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Abstract: In our life, electricity is an indispensable energy. Furthermore, environmental problems represented by global warming are attracting attention. Currently, in Japan, more than 3,000 micro wind turbine generators have been introduced. However, there still is little introduced into general homes. Micro wind turbine generator has various problems such as energy is not stable, power generation amount is low, installed cost is high, and so on. As an example of the installation of micro wind turbine generator in Japan, it is the current situation that it is set as a symbol of environmental protection, facilities for education in public facilities and personal hobby. If popularization in general households progresses, it can be used as an emergency power source in the event of earthquake disaster or power outage, which are successive in recent years, leading to the securing of the power energy required for lighting and communication equipment. In this research, consider the problem of the micro wind turbine generator and the vertical axis type micro wind turbine generator that the introduction into the ordinary homes is easy manufacture. We will investigate maintaining its performance and aim to create a wind turbine rotating at about 3 [m / s], the average wind velocity in Japan, for practical use. As first, It did the design and product of the micro wind power generation which installed a movable blade.

Keywords: the micro wind turbine generator ; TSR ; Betz's limit ; starting equipment

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1. Introduction

At present, the introduction of the micro wind turbine generator system of equal to or less than several kW of output in Japan, too, is extensively done and equal to or more than 3000 small wind turbines are turning around the country already.

However, there is a numerous problem in the introduction of the micro wind turbine to have turned to the ordinary homes from the viewpoints such as the generating efficiency and the safety and the view fault, too [1].

As the establishment example at the small wind turbine in Japan, the establishment about the power at the cottage, the symbol and the monument, the education teaching material equipment in the public facilities, the independent back-up power of the non- common use, the hobby of the individual is the present situation.

Many of Savonius-type and so on Darrieus-type are therefore reported to the structure of the present micro wind turbine [2].

It is possible for the self to start up about most of the commercialized micro wind turbines.

Then, the blade-shaped windmill with high efficiency is general.

In this research, it is implementing easily to the ordinary homes business to practicalize the wind turbine which it is possible to introduce.

It developed the micro wind turbine of rated output 3W (Max=5W), the direct current power generation with three sheets of wings.

Therefore, it is doing the basic characteristic of the small windmill, and a performance and the problem of the introduction in the ordinary homes and the spadework to improve [3].

In the this paper, using the developed micro wind turbine, it measured an output-characteristics and it reviewed the verification of the wind speed and the power generation electric current and the power generation voltage and a start-up performance at the low wind speed.

2. Experimental Setup

A survey at the vertical type micro wind turbine to be using by this research is shown in figure 1. It designed rotor figure in the vertical axis form. It makes windmill diameter 460[mm], windmill basic-machine-weights about 0.6 ㎏, blade material a balsa, it makes a start-up a motor start-up method and the survival wind speed is 15 [m/s] as 5 [m/s] of rated wind speeds, the strong wind measure.

Figure 1. the vertical type micro wind turbine.

A measurement instruments is shown in figure 2. The measurement installs a wind turbine in Cage with height 2000[mm], at the actual natural-wind, it makes a fixed resistor a load and connects a 6 - 12 [V] lead-acid battery (made by GS Yuasa Corporation; EB100). In the generation electric current and the Generation voltage.

The flow divider changed the power generation electric current into the voltage and it did an automatic-gaging with the computer through the SIGNAL RECORDER (made by the Velleman;PS10/K8047). It measured a wind speed at the same time with the wind gauge (made by CUSTOM; WS-02).

The change of the output power and the wind speed to the wind speed is shown in figure 3.It made an output power the value which multiplied a battery voltage to the power generation electric current. The low wind speed area which occupies a lot of areas in Japan is 3 [m/s] of annual average wind velocities [2].

Table 1. Specification of micro wind turbine

Parameter	Characteristics
Rated power (W)	3
Rated wind speed (m/sec)	4
Cut-in wind speed (m/sec)	1.5
Cut-out wind speed (m/sec)	15
Wing material	wood
Number of blade	3
Rotor diameter (mm)	460
High wind safe mode	stop
Output Voltage (V)	5
Weight (kg)	6

Also, it is possible to confirm that equal to or less than 2.5[m/s] wind speeds of turn of the blade part are being sufficiently done on the characteristic of the generator. It makes 6 dial type variable resistance a load and it acquires a characteristic with electric current and voltage.

Also, it measured number of rotations by the non-contact type TACHOMETER (HT-4100; Ono Sokki Co., Ltd.). The wind speed changes from 1 [m/s] to 10 [m/s] by the 1 [m/s] carving and it recorded number of rotations of then and the wind power generator, and a generated-voltage, a load-current.

Then, if the wind speed reached 10 [m/s], this time, it changes to 2 [m/s] by the 1 [m/s] carving and it recorded in the same way. The theory type with gotten energy [4] [5]. The energy [W] which is theoretically gotten from the vertical axis type wind turbine is found from the following equation.

$$Pw = \frac{1}{2}\rho A V^3 C_p[\text{kgm/s}] = 4.9\rho A V^3 C_p[\text{W}] \tag{1}$$

where, it is ϱ ; It is air density (0.129)[kg/m3], A ; The windmill exposed area for wind [m2] A＝2Dh/3,　D is the diameter of the windmill. V ; The wind speed [m/s] , h ; The height of Blade[m], Cp ; The power coefficient (General 0.3-0.4) [kg･m/s]. Equation (1) shows that PW is proportional to the exposed area for wind (figure 3) at the windmill and that it is proportional to the 3rd power of the wind speed.

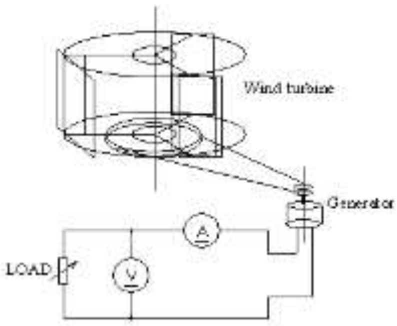

Figure 2. Experimental set up.

On the other hand, a rate with the energy which the natural-wind has and the energy (the output) which it is possible to take out from the windmill is known as the power coefficient CP.

There is a limit in this value and in case of the ideal windmill, the maximum becomes CP=0.59. This value takes the name of the scholar who found out this coefficient and is said to that it does Betz's limit.

$$P_{out}=P_W\eta_a\eta_g\eta_c \tag{2}$$

where, it is η_a ; The efficiency [%],η_g; The efficiency of the speed-increasing gear [%],η_c ; Efficiency of the control and the converter of the generator [%], When for example, make C_P=30[%], ηa=90[%],
$Pout = 0.276 \times 0.9 \times 0.8 \times 0.8 = 0.159$[W] , ηg=80[%], ηc=80[%],

Generally, the average wind velocity is 4 - 6 [m/s] at most in the area with strong wind, but the storm blows at the time and the wind speed sometimes becomes 15 - 20 [m/s].

The efficiency which changes the energy of the wind into the mechanical power with the windmill out of the overall efficiency of the wind power generator is called a power coefficient. A transverse is a peripheral speed ratio but is defined at the speed V_B [m/s] of the direction of rotation with the optional position of the blade and ratio (=V_B/V) with wind speed V [m/s]. Also, the peripheral speed ratio can be computed from the number of rotations.

Generally, the most advanced peripheral speed ratio of the blade is called TSR, too

$$\lambda = \frac{\omega r}{V} = \frac{\pi D n}{60 V_\infty} \tag{3}$$

But, ω ; Angular speed [rad/s], V ; The wind speed [m/s] , n ; The number of rotations [min^{-1}], r ; The radius of the windmill [m], D; The diameter of the windmill[m]

$$\lambda = \frac{\pi D n}{60 V_\infty} = \frac{\pi \times 0.4 \times 100}{60 \times 6} = 0.34$$

This power coefficient C_P depends on the kind and the shape, the number of rotations of the windmill but can be called the windmill which is excellent if the blade type windmill becomes C_P =0.35-0.45.

When for example, make D=0.4[m], n=100[min^{-1}], V=6[m/s] The torque which occurs with blade is proportional to the square of the wind speed. The voltage which occurs with the generator is proportional to the number of rotations approximately. Moreover, because the number of rotations is proportional to the wind speed, if making the load-current of the generator the characteristic as proportional to the square of the power generation voltage, maximum output is always gotten.

3. Result and Discussion

Generally, the higher the number of rotations of the generator is, the bigger the output becomes and the efficiency improves. Figure 4 shows the power generation voltage of the micro wind turbine generator to the wind speed. The power generation has begun from wind speed 4-5[m/s].Figure 4 shows the generated-output of the micro wind turbine generator to the wind speed. It is proportional to approximately the 3rd power of the wind speed.

Arithmetic expression (1), (2) are shown but fully, it doesn't apply. That the generated-output occurred at the 4[m/s] wind speed distinguished between the developed micro winds turbines from this research result.

It found that it generated an equal to or more than 10 [mW] output powers when becoming a wind speed with equal to or more than 7.0 [m/s] wind speed. It found that the developed micro wind turbine was the windmill

Which generates an equal to or more than 60 [mW] output powers when becoming a wind speed with equal to or more than 8 [m/s] wind speed.

To have described in the beginning, it puts an igniting arrangement as shown in figure 5 to this wind power generator. Figure 6 shows the starting equipment. Unfortunately, with this design, the objective could not be achieved. It becomes difficult to raise the revolution mechanically from this thing. Therefore, it used aluminum Pulley for the increase of value. In the generator output voltage, therefore, using the DC-DC converter of the step-up, it tries to implement entry 1.5[V]-3[V], output 12[V].

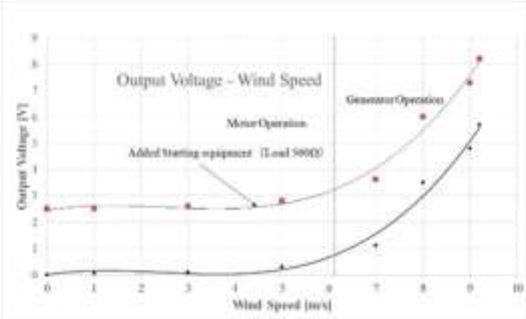

Figure 3. Output Voltage VS wind speed.

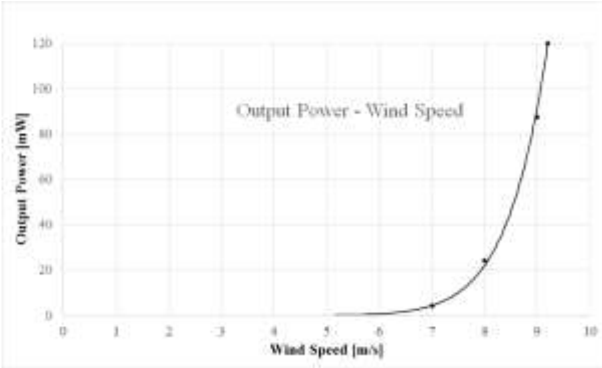

Figure 4. Output power VS wind speed

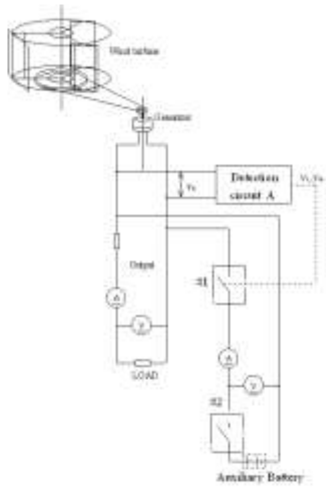

Figure 5. Added the starting equipment

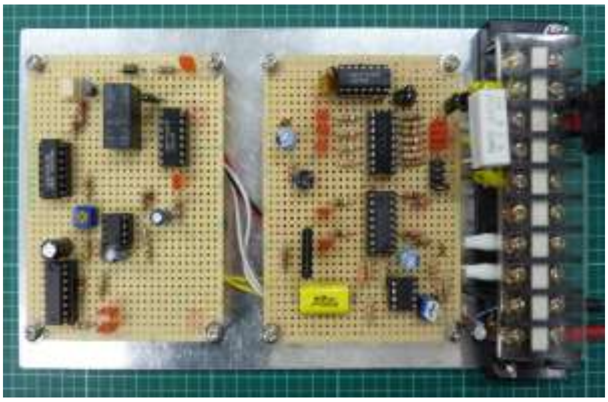

Figure 6. The starting equipment

4. Conclusions

Unfortunately, with this design, the objective could not be achieved. It becomes difficult to raise the revolution mechanically from this thing. Therefore, it used aluminum Pulley for the increase of value. In the generator output voltage, therefore, using the DC-DC converter of the step-up, it tries to implement entry 1.5[V]-3[V], output 12[V].

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