FEASIBILITY STUDY OF HYBRID ENERGY GENERATING SYSTEM

(Wind tunnel test)

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ABSTRACT

A hybrid energy generating system that can use both solar energy and wind energy is proposed. The outlook of this system is like a flower having several pedals. In sunny days, it opens and assembles solar energy by the mirror surface of panels, while in cloudy and windy days it closes and rotates to transfer wind power into electric power. The performances of two different prototypes (Type A and Type B) as electric generator are examined by wind tunnel tests. Type A is composed of six panels (50cm x 10cm). Type B is composed of twelve panels (50cm x 12cm) with six of them located inside and the other six located outside. The surfaces of the panels have parabolic shape to focus solar radiation at one point. The parameters of the wind tunnel tests are wind speed (3m/s~20m/s), panel angle (15°~83°), measured from base line on rotating circle and inclined angle of rotating axis (-30°~+30°). As experimental results of Type A, the number of revolutions per minute (RPM) increases proportional by to the square of the wind velocity and Type B, RPM increases linearly by to the wind velocity. The maximum RPM are obtained at the case of panel angle = 60° for Type A, outside panels angle = 60° and inside panels angle = 30° for Type B, respectively. The maximum electric power is 80W in the case of 15m/s for Type B. RPM decreases by about 10% when the inclined angle is in the range of -30°, +30°.

Keywords: Hybrid generating system, renewable energy, wind tunnel test

1. INTRODUCTION

In the past, high standards of living and modern lifestyles were based on increased energy consumption. Today, statistics from highly developed countries show that standards of living can increase independently of energy consumption if energy efficiency measures are introduced. In 1999, the global demand for electricity was about 14,764 x 10⁹ kWh. This demand was met mainly through fossil fuels and nuclear power. Renewable energies were only 2% share. To decrease air pollution and peril of nuclear energy, highly developed industrial countries, have started to limit their energy consumption, without decreasing their living standards, by encouraging energy efficiency and energy efficient

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technologies. These energies include wind power generation and photovoltaic generation. Recently, the wind power generation uses two or three blades (Horizontal axis rotor) and the blades size are going to be bigger until now. However, large scale horizontal axis rotor is pointing to wind direction and is making a noise during rotation of its blades. In this paper, new hybrid energy generating system is proposed. Usually, the wind generation system consist two or three blades but this system is consisted six panels and rotates like a cup anemometer (Vertical axis rotor). This hybrid generating system concerns about neither wind direction nor noise against wind. The objective of this paper is to find out the relationships between panel’s angle and wind speeds and the relationship of center pole against the wind direction.

2. STRUCTURAL MODEL

Two different prototypes (Type A and Type B) are examined their functions in regard to electric generator by wind tunnel tests. Type A is composed of a center pole and six panels which can rotate around the center pole. Those are made of stainless steel. Each panel is 50cm length, 10cm wide and 2mm thickness. Those panels have two functions. One is to concentrate solar energy to the center pole. So their surfaces curved along parabolic shape, and the other is to play rotor blades for the electric generator. These two functions are selected by open and close mode of blades. In this paper only the second function is examined by wind tunnel test. The configuration of Type A is shown as Fig.1.

Fig. 2 shows the shape of Type B composed of 12 panels, in which 6 panels are supported by inner circle plate and other 6 panels are supported by steel bar fixed on inner circle plate as shown Fig. 2 (a). The diameter of inner circle plate is 30cm and the distance from center bar to the outer edge of steel bar is 49cm. In Fig. 2 (b), illustrates elevation plan.
The height of Type B is 60cm, and each panel is 50cm length and 12cm wide. Every panel size is same and each panel open to select solar radiation as shown Fig. 2 (c). However, its panel closes to rotate its generator as shown in Photo.2 (a). The location of inner panel and outer panel is different so that to avoid bumping against each other and able to use every kind of wind. Including, low and high speed wind. Outer panel is effective at low and middle speed wind while inner panel is effective at high wind speed.

3. WIND TUNNEL TEST

3.1 Model for wind tunnel test

Type A is tested in wind tunnel using stainless panel shown in Photo.1 (a). Wind tunnel test examines with changing wind speed and panel angle (α) where the panel angles are measured from base line on rotating circle and inclined angle of center pole (β). The angle of panel (α) is 15°, 30°, 45°, 60°, 75° and 83° and center pole (β) also moves +30° to -30° in wind direction to find out affection of mountain-top-mountain-valley-wind. The wind speeds used are 5m/s, 10m/s, 15m/s and 20m/s. Photo 1 (a) shows the test model in wind tunnel and photo 1 (b) is the outlook for using solar energy when it is not windy day or low wind power area. Type B is designed by the shape of the Type A and improved form Type A. In Type B, to increase the power coefficient, section of the panel is designed like young moon. In the panel section, inner curve is designed by parabola to concentrate solar radiation at one point and the other curve reduces resistance of adverse wind. Type A consists of six reflection panels and the Type B consists of twelve reflection panels as shown Photo1 and 2. In Type B, inner panel diameter is 30cm and outer panel diameter is 45cm. Each panel focuses solar radiation above 15cm on the vertical point of reflection panel surface. Compare to panel material, Type A uses steel but Type B is changed wooden panel to decrease its weight. In the case of Type A, weight of one panel is 1.4kg but panel weight of Type B, about 1.15kg is decreased. And width of panel also changed.

(a) Using wind energy
(b) Using solar energy

Photo 1. System shape of Type A

In the case of Type A, 10cm panel width but Type B is increased 2cm compare to Type A. In addition to Type B, a generator (E020) is installed to produce electric power. Photo 2 (a) shows the shape of using wind power, and photo 2 (b) shows the shape of the system uses solar energy. Type B experiments in wind tunnel like as three pairs of Savonius type. Two kinds of testing are performed in Type B. One is with light bulb (12V, 35W) that is working in generator as electric resistances and the other is without light bulb. The angle of inner panel (χ) and outer panel (δ) in type B changes to 30°, 45°, 60°, 90° and 3m/s, 5m/s, 8m/s, 10m/s, 13m/s, 15m/s wind speed is tested. In the case of Type B, the center pole (β) is fixed at 0° because the affection of changing center pole angle (β) is cleared at the test of Type A. In this experiment, the conveyor belt is connected with generator and center pole. This conveyor belt uses two kinds of transmission rate 1:1 and 1:2. In the case of 1:2, the generator has 1 rotation when center pole has 2 rotations.
3.2 Ability of generator (E020)

Fig.3 is shown results of generator (E020) ability. Electric power with electric resistance and without electric resistance is shown as Fig. 3 (a), (b) respectively. When the E020 rotates 320 per minute, 200W of electric power is produced as a rated electric power and 8.97N.m torque. The weight of E020 is 12.6kg, 312mm diameter, 77mm height and rated voltage is AC 12V. A 3 phase electric cord is installed in E020.

4. RESULT OF WIND TUNNEL TEST

4.1 Results of Type A

The relationship between panel angle $\alpha$ and the number of revolution per minute (RPM) are shown as Fig4. (a). Center pole angle $\beta$ (affection of mountain-top-mountain-valley-wind) and RPM are shown as Fig4. (b). Fig2. (a), it appears the optimum angle $\alpha$ that is the maximum value of RPM (480) is about 60° in 20m/s wind speed.

But the differences of angle do not affect RPM in the range of 45° $\leq \alpha \leq$ 70°. In the range of 0m/s $\sim$ 5m/s, RPM is very low and after 5m/s the rotation increases proportion by to the wind velocity until 15m/s. A slight decrease of gradient can be observed in the range of 15m/s $\sim$ 20m/s. This result suggests that the proposed model reduces RPM for strong wind
more than 20m/s. This tendency will be desirable from the viewpoint of structural safety, overspeed control secondary protection systems.

4.2 Results of Type B

Fig. 5 shows the results of Type B. Fig. 5 (a) and (b) is without a light bulb, and (c) and (d) is with a light bulb. Fig. 5 (a) is the case of inner panel ($\chi$) fixed 30° and outer panel ($\delta$) can be changed 0° ~ 90°. The maximum value of RPM is obtained at 60° outer panel without generator. Fig. 5 (b) shows the number of RPM when $\chi$ = 60° and 273 obtained RPM at 30° outer panel ($\delta$). This value is the maximum RPM in Type B with 15m/s wind speed. Fig. 5 (c), (d) is the results of Type B have electric resistance in generator. In the case of Fig. 5 (c), $\alpha$ is fixed at 45° and the maximum RPM value is 188 with 15m/s wind speed. In the case of $\alpha$ is fixed at 60°, the maximum RPM value is 211 with 15m/s wind speed as shown Fig. (d). The 200RPM with electric resistance and 270 without electric resistance, about 80W electric power and 13V voltage (AC) is produced as shown Fig. 3 (a) and (b), respectively.

Fig. 5. Results of Type B in wind tunnel test

4.3 Consideration

Type A and Type B are experimented in the wind tunnel. In the case of Type A, the maximum number of rotation is obtained about 480 RPM with 60° panel angle and 20m/s wind speed. And the panel angle of 45° ~ 70°, the number of RPM is similar value as shown Fig. 4 (a). As the center pole is changed to angle = -30°, +30°, the RPM value is decreased about 10% compare to the fixed center pole as shown in Fig. 2 (b). In the case of Type B, the maximum number of rotation is obtained about 270 when the 60° outer panel angle and 30° inner panel by introducing 15m/s wind speed without electric resistance, 13V voltage is obtained as shown in Fig. 3 (b) and Fig.5 (d). At the 10m/s and 15m/s wind speed, 40W and 80W electric power is obtained respectively as shown Fig. 3 (a) and Fig.5 (d). In the case of introducing electric resistance, about 10% voltage is reduced. If Type B connects to battery (very low
electric resistance), about 150W electric power produces as shown Fig. 3 (a).

4 CONCLUSIONS

A hybrid energy generating system that can use both solar energy and wind energy is proposed. The outlook of this system is like a bloom in open panels and like a bud in close panels. In sunny days, it opens and assembling solar energy by mirror surface of panels, while in cloudy and windy days it closes and rotates to transfer wind power into electric power. The performances of two different prototypes (Type A and Type B) as electric generators are examined by wind tunnel tests. Type A is composed of six panels. Type B is composed of twelve panels where six panels are located inside and the other six panels are located outside. Those surfaces of the panels have parabolic shape to focus solar radiation at one point and to use different wind resistance coefficient in the panel section. As the wind tunnel test of Type A, in the range of 0m/s ~ 5m/s, RPM is very low and after 5m/s, the rotation increases proportion by to the square of the wind velocity until 15m/s. A slight decrease of gradient can be observed in the range of 15m/s ~ 20m/s. This result suggests that the proposed model reduces RPM for strong wind more than 20m/s for structural safety, overspeed control secondary protection systems. As the results of the Type B, RPM increases linearly by to the wind velocity in the range of 0m/s ~ 15m/s. The maximum RPM are obtained at the case of panel angle = 60° for Type A, outside panels angle = 60° and inside panels angle = 30° Type B, respectively. The maximum voltage is 13V (without light bulb) and 80W (with a light bulb) in the case of 15m/s for Type B. As the affection of mountain-top-mountain-valley-wind, RPM is decreased about 10% in this system.

REFERENCES