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Effects of the arm cross-sectional shape on the aeroacoustic noise of a straight-bladed vertical-axis wind turbine

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Abstract:

Vertical-axis wind turbines (VAWTs) are generally omnidirectional and more suitable than horizontal-axis wind turbines for built environments in which the turbulence intensity is usually high. In a built environment, noise issues tend to be more significant than in rural areas due to the close proximity of people. Therefore, noise reduction technologies for VAWTs are necessary; however, the number of existing researches related to VAWT noise is extremely limited, and the primary noise source has not been clarified. In our previous research, we found there is a high possibility that the VAWT’s primary noise source involved the interaction of the vortices emitted from the trailing edges of the upwind blades with the arms of the VAWT. Thus, the present study aimed to clarify the effects of the arm cross-sectional shape on the aeroacoustic noise of the VAWT.

The measurement of the sound pressure of the VAWT was conducted with a wind tunnel experiment using a microphone array. The wind tunnel used was an open-circuit type, and the cross-sectional size of its outlet was 1.15m × 1.15m. The VAWT, the wind tunnel outlet and the inlet were set in a 3.2m × 3.5m × 3.4m anechoic room. To avoid any reflection of noise, the inner walls of the wind tunnel were covered with urethane foams. The VAWT’s diameter was 0.8m, its blade span length was 0.8m, and its chord length was 0.2m. The airfoil shape was NACA0018, and there were three blades. The cross-sectional shape of the arms varied through the use of arm covers made of ABS resin. The cross-sectional shape of the arms was elliptic; the vertical length was 50mm, and the horizontal length varied from 40mm to 60mm. The microphone array was composed of 4 × 4 microphones and was set above the VAWT to obtain the horizontal distribution of the sound pressure. The distance between each microphone was 0.3m.

At a tip speed ratio of $\lambda = 1.2$, which is near the optimum tip speed ratio, it was confirmed that the noise level increased with an increase in the horizontal length of the arm cross-section. In addition, the noise level was higher near the rotational center of the VAWT?in particular, on the side where the blade moved against the streamwise wind. Regarding the power coefficient, it decreased with a decrease in the horizontal length of the arm cross-section, and this tendency was more remarkable at a mid to high λ.

Development of rotation flow VAWT for pumping system

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Abstract:

Recently, horizontal axis wind turbine (HAWT) using lift force acting on the blades is popular for wind power generation. The scale of wind turbine is getting bigger in order to reduce Cost of Energy for the mass-consumers of electricity in urban area.

On the other hand, small scale vertical axis wind turbine (VAWT) have been used for special purpose. The authors developed so-called ‘Rotation Flow Wind Turbine’ which uses drag force1), and more than one hundred of wind turbines were installed to generate small power for LED lump above the snow shielding fence since 20112). From this experiences, this type of VAWT was proved to generate big torque to start-up, silent and easy for maintenance.

Additionally, for the fishery area at northern part of Japan, some functions (melting the snow, pumping of water and so on) do not need continuous supply of power. This paper will focus on the torque generation, and development of ‘Rotation-Flow Wind Turbine’ VAWT for pumping system.

The configuration of VAWT was parametrically changed, and aerodynamic performance was tested by installing above the roof of running car. Then CFD analysis was also conducted in order to understand the mechanism to generate torque.

References)

1) Hirotada NANJO, ‘Dynamical Model and Estimation for the Optimization of Output Power by Reaction Type Wind Turbine’, Journal of JWEA, Vol.32, No.4, 2008 (in Japanese)

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Micro SAVONIUS for remote Area

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Abstract:

The Savonius windmill, has been researched, developed, and tested for practical use for developing nations, a non-electric area and as temporary wind turbine power source. The structure of the windmill is very simple. Its efficiency is very high since it captures wind from all directions and at very low speeds. The Savonius system is a “micro wind power generator system"" and it has significant value statements. It is extremely portable. It is also easy to install and operate. During the testing phase, the Savonius system maintained stable power generation for nearly 10 years at less than 1 kW/h. The success of the Savonius testing phase has allowed the focus to shift to practical applications. The Savonius system consists of a windmill, a generator, a battery, and an electronic control circuit that includes effective security protocols.

1. The Rotor for SAVONIUS Wind Turbines

- The Savonius system is a windmill.
- It is cheap, efficient, and capable of processing continuous power.
- Its construction is simple and it poses little environmental hazard.
- The essential components of the windmill are paper, bamboo, and organic cloth.
- It is easily repairable and has a long operable lifespan.

2. The Generator

- In addition to the existing motors for home appliance, the magnetic circuits and control system are newly developed and are designed to provide maximum energy conversion and longevity in low efficiency conditions.

3. The Battery

- The system uses a low-cost lead storage battery power source. The windmill uses a nickel hydrogen system. Lithium ion batteries are also practicable.

4. Electronic Control circuit

- The generation of electricity adopts the latest electronic circuitry and loT technology. The goal is to maximize the system's durability. The circuitry optimizes the windmill's ability to generate power at wind speeds from slight breezes to wind storms.

Experimental Study on the Effects of Relative Rotor Location to Duct Exit on Energy Recovery from Duct-Exhaust Flow Using a Butterfly Wind Turbine

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Abstract:

Duct-flow power generation (DFPG) is an energy recovery method in which small wind turbines are used to generate electricity from the fluid energy flowing out of an exhaust duct. In the previous report, the validity of DFPG has been demonstrated by experiments and two-dimensional computational fluid dynamics. However, in those experiments to obtain the energy recovery rate, a wind turbine was located only on the centerline of exhaust flow.

To investigate the effects of relative rotor location to duct exit on energy recovery, the similar experiments are conducted by installing a wind turbine away from the centerline of exhaust flow in this study.

A Butterfly Wind Turbine (BWT), which is a vertical axis type with three looped blades, is used as the experimental rotor. The diameter is D=0.4m, height H=0.3m. A wind tunnel with the square nozzle of width W = 0.65m is utilized as an exhaust duct. The origin of a coordinate system is set at the center of the nozzle-exit. The BWT is positioned at one of 15 locations, which are designated by combination of the coordinate values of the mainstream direction X/D＝1.25, 1.875, 2.5, 3.125, 3.75 and the lateral direction Y/W=－0.46, 0.0, 0.46. In each configuration, wind speed distribution on the nozzle-exit section (Y-Z plane at X = 0) is measured by using Pitot tube under the condition of constant base wind speed of 6 m/s.

The maximum power coefficient of the wind turbine was Cp = 0.13, which was obtained in the case of rotor location of (X/D, Y/W) = (1.25, 0.46). The energy recovery rate η is defined as follows:

$$\eta = \frac{P_{WT} - \Delta P_{KE}}{P_{KE0}} \quad (1)$$

where PWT is the shaft power of the turbine, PKE0 is the fluid kinetic energy flowing out of the wind tunnel when a turbine does not exist, and ΔPKE is the loss of kinetic energy due to existence of the turbine. The maximum η was 2.7%, which was obtained when (X/D, Y/W) = (3.75, －0.46). The product ξ of the power coefficient Cp and the energy recovery rate η is defined as an indicator to evaluate the effectiveness of DFPG. Relatively great values of the indicator ξ were obtained when the turbine was installed at (X/D, Y/W) = (2.5, －0.46), (3.125, －0.46), and (3.75, －0.46). This shows that the turbine locations where a drag-type rotor works well might give better configurations for DFPG at downstream region.

Study of a casing with two flow deflector plates for performance improvement of a cross-flow wind turbine by CFD analyses

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Abstract:

Our study is for performance improvement of cross-flow wind turbine for small size wind power generation.

The cross-flow wind turbine is a kind of Vertical Axis Wind Turbine, so it has undesirable part of swept area where blades moves in opposite wind direction and a wind into this part prevents the turbine rotor rotating. If this wind could be blocked, the performance of cross-flow wind turbine would be improved. By the way, at the corner edge of structure such as building, flow separation generates. Therefore, in our previous study, the performance of a cross-flow wind turbine near the corner edge of structure was examined by wind tunnel test using a small size test model (rotor diameter is 114 mm, blade chord length is 20 mm and the number of blade is 12). In this case, the undesirable part of swept area of cross-flow wind turbine was in the separated flow generated at the corner edge of structure. As a result, the cross-flow wind turbine near the corner edge of structure showed higher performance than the cross-flow wind turbine without the corner edge and in uniform flow. In our present study, some ways to get higher power output of cross-flow wind turbine even in uniform flow without structure like a building have been investigated and based on above previous study, a casing with two flow deflector plates and tail plate was devised. The two flow deflector plates are to improve ambient wind environment of wind turbine and the tail plate is for attitude control of the casing to face toward the wind. This casing is set on turbine rotor axis with bearings so it can rotate around the axis. One of flow deflector plates (FD-A) is set by the side of turbine rotor where the blades travels in wind direction and it has some angle of attack to generate accelerated flow into turbine rotor induced by flow separation at its leading edge. Another flow deflector plate (FD-B) to block undesirable wind entering into turbine rotor is set vertical to wind direction and in front of the undesirable part of rotor swept area. So far, by using flow deflector plates with 20 mm length, for a case that FD-A is set with 30 degrees angle of attack and 13 mm apart from turbine rotor and FD-B is set 60 mm upstream from the center of rotor axis with making about 17% closed swept area, the performance of cross-flow wind turbine was examined by wind tunnel tests and CFD analyses. A result showed that the maximum power output was about 60% higher than that in the case without flow deflector plates. Then, another case that FD-A moves 10 degrees around rotor axis for upstream and FD-B moves 5 degrees to make blocked wind flow into turbine rotor was evaluated by CFD analyses. As a result, the cross-flow wind turbine under this case showed higher maximum power output by about 7% than the above case.

Experimental and Numerical Investigation of Orthopter-type wind turbine in a shear flow

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Abstract:

Introduction: Wind turbines are installed near a tall building to increase the electric power because the wind of speed increases near the corner of a tall building. However, the flow profile has velocity gradient. The effect of the position in a shear flow on the performance of vertical axis wind turbines needs to be investigate to install near buildings for a practical use. The orthopter-type wind turbine is one of a variable-pitch vertical-axis wind turbine with the straight blades like the paddle-type vertical-axis wind turbine. In this study, wind tunnel experiments and numerical simulations were conducted to investigate the performance of the orthopter-type wind turbine in a shear flow and clarified the optimal condition to operate. Experiment Setup and Numerical Technique: The experiments were carried out in an open circuit wind tunnel. The diameter and height of the orthopter-type wind turbine are D = 510mm and h = 400mm, respectively. The number of flat plate blade is three. The pitch angle of the blades was controlled by using a chain and sprockets arrangement to ensure that the blades rotated around their own axis by 360 degrees during the each two full revolution of the main rotor. To create a shear flow, the porous plate with the splitter plate was installed at the wind tunnel outlet. The porous plate was used to change the strength of a shear flow. Three shielding coefficients, which are the ratio of the shielded area to the area of plate, was considered $\Phi = 0.49$, 0.60 and 0.67. Two type positions of the porous plate, i.e. “Forward side” and “Backward side”, and the location of the porous plate to the center of wind turbine in a shear flow, Ψ (= y/D), were examined. A two-dimensional numerical simulation of the wind turbine was performed using the ANSYS Fluent 15 software at the flow conditions corresponding to the experiment. Unsteady Reynolds Averaged Navier Stokes equations were solved and RNG k-ε turbulence model was used.

Results: The obtained results are summarized as following.

(1) The numerical simulation results agree with the experiment results qualitatively. The effects of the location of the wind turbine and the strength of a shear flow on the performance of the orthopter-type wind turbine were found.

(2) In case of the forward side of the porous plate, the power decreased in all shielding coefficient Φ than one of no plate, i.e. in the uniform flow. In case of the backward side, the power increased with increasing the shielding coefficient Φ than one of no plate.

(3) The orthopter-type wind turbine mainly rotates by the rotational moment of the drag force of blades in forward side. The drag force of blades in backward side prevents the rotation of the wind turbine. Therefore, the power of orthopter-type wind turbine increases when the wind speed in the forward side of wind turbine ($y < 0$) is larger than that in the backward side ($y > 0$).