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Performance Prediction of Triangular-Blade Butterfly Wind Turbine with Mechanical Over-Speed Control System

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Abstract:

A passive over-speed control system (OCS) is effective for wind turbine systems because it increases the safety and reduces the cost of energy by expanding the capacity factor. A mechanical OCS, which uses centrifugal force to twist a blade working as air-brake, for small-sized vertical axis wind turbine (VAWT) has been developed by Tottori University.

New project started in 2016 aims at developing a 7m-class VAWT with OCS. As the preliminary study, the performance of the planned triangular-blade butterfly wind turbine (TB-BWT), which is an armless VAWT consisting of 5 looped blades, is predicted. The rotor diameter is about 7 m, the rotor height is 2.7 m, the chord length is 244 mm, and the blade section is NACA 0018. The blades are made by extrusion of aluminum and the weight of one blade is estimated to be approximately 36 kg. One unit of OCS consists of a blade-axis rod, a guided pin, the guiding grooves and a helical spring.

Five units of OCS are connected each other via a disk for synchronization at the rotor center. The turbine performance is predicted by Quadruple-Multiple Streamtube model based on the Blade Element Momentum theory, adding the mechanics of force balance between the centrifugal force and the restoring force of spring in the case with OCS. In the case of TB-BWT without OCS, which is assumed to cut out at wind speed of 13 m/s, the maximum output power of about 6000 W is predicted at 12m/s, rotor rotational speed of 130 rpm. In the case of TB-BWT with OCS, although the predicted output is the same as that of the turbine with OCS under the conditions of low wind speed and low rotational speed, the output is suppressed at 8m/s (90 rpm) or more. However, the TB-BWT with OCS is expected to keep the rotation at the high wind speed conditions, and the maximum output of 3800 W is predicted under the conditions of 15 m/s and 116 rpm, when the blade-twist angle becomes 14 degrees. When the wind speed is more than 16 m/s, the TB-BWT with OCS might not have a stable operating point, i.e. a cross-point between the turbine and the generator torque curves, theoretically. Therefore, in this study, two cases regarding the behavior of turbine are assumed. As the first case, the maximum output power is assumed to be held constant at high wind speed. As the second case, the output is assumed to fluctuate even at a constant high wind speed, giving the averaged output corresponding to the half of the maximum power. The prediction of the annual energy production by using Rayleigh distributions of wind probability gives almost the same results to the two cases with OCS and the case without OCS at the annually averaged wind speed of 6 m/s or less. About 6000 kWh is expected to be generated per year at the average wind speed of 5 m/s by the TB-BWT with OCS and a 4kW-class generator.

Numerical Analysis of Flow Field around an Endplate of Straight-Blade Vertical Axis Wind Turbine

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Abstract:

To mitigate the tip loss, an endplate is often installed on the tip of a turbine blade. In this study, the optimum size of an endplate attached to a straight-bladed vertical axis wind turbine (VAWT) is investigated by three-dimensional computational fluid dynamics (3D-CFD). The flow field around the endplate, especially vorticity distribution, is focused to find out the differences between cases with and without the endplates.

Two-bladed H-Darrieus VAWT, whose size is the same as the experimental rotor of TU Delft (DU-H2-5075), is selected as the computational model in this study. The rotor diameter is 0.75m; the blade span length is 0.5m; the blade chord length c is 0.08m. Although the experimental rotor does not have any endplates, the computational model of the present study is assumed to have endplates (thickness :1 mm) whose outline is defined to jut out uniformly with a distance s from the edge of the blade cross section (NACA 0018). Seven cases of the ratio of the jutting out, i.e. s/c = 0.0, 0.0375, 0.0625, 0.09375, 0.125, 0.1875, and 0.25, are analyzed. The rotational shaft and the horizontal arms of the rotor are not considered in this study. In the computation, the wind speed is assumed to be 7 m/s and the rotational condition of the tip speed ratio of 3.25 is selected, which corresponds to the maximum-power state of the rotor.

STAR-CCM+ is utilized as the CFD solver. The analysis is based on the three-dimensional and incompressible unsteady Reynolds averaged Navier-Stokes (URANS) equations. The SST k-ω turbulence model is used. The total number of cells is about 7,860,000 in the case of s/c = 0.0625, for example. The time step is set to the value that gives a rotor rotation of 0.5 degrees per step. The computation is carried out until the rotor finishes 6 revolutions, which give the almost converged power coefficients.

As the results, the maximum power coefficient is obtained in the case with endplates of s/c = 0.0625 and increases 7.54 % compared to the case without the endplates. In other words, too large endplates might increase the surface friction and result in the reduction of mitigation of the tip loss. The decrease in vortex intensity produced from the blade trailing edge is observed near the rotor equator region in that maximum power case. Without depending on the existence of the endplates, main vortex is formed near each side (inner-side and outer-side) of a blade tip. Other minor vortices are also formed near the blade tip. The details will be discussed at the conference.

Optimum Configuration of Wind-Diesel Hybrid System -Case Study in Baragoi, Samburu County, Kenya-

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Abstract:

This paper shows the results of pre-feasibility study on wind - diesel hybrid power generation system at Baragoi, Samburu County in Kenya. At Baragoi, wind speeds and directions have been monitored at 20 meters and 40 meters above ground level respectively by Ministry of Energy and Petroleum. In this study, wind characteristics such as frequency of wind speed and wind direction were examined based on the data monitored for a year. In addition, energy output from a wind turbine is estimated. There is an autonomous diesel power station in Baragoi which supplies electricity to customers in the area. The capacity of the existing diesel generator is 300 kVA. Operational data of the diesel power station was summarized and analyzed in the study. Furthermore, economical aspect of the project was evaluated.

The conceptual design of hybrid system with existing diesel power station was studied.

The system under study is suitable for an area where connection to the national grid is economically not feasible due to long distance to nearest existing transmission line and small energy demand with few users. The main purpose of this hybrid system is to enable the Diesel generator to reduce fuel consumption. For this to be achieved, the most important factor considered is wind penetration. The importance is to be able to estimate how much energy can be drawn from wind since this determines the level of system complexity. The second important parameter to be investigated in the design was the frequency of the power system because it needs to be regulated.

The research findings proved that a low penetration system is suitable for Baragoi. Considering also that low penetration is useful for acquiring experience of a Wind-Diesel hybrid system.