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A Dual rotor wind turbine a technology of future

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Abstract

A dual rotor wind turbine having two rotors rotating in same or in opposite direction the same axis has been proposed as a new concept to enhance the maximum power coefficient of a wind turbine .It is predicted that the turbine operates in isolation, numerical analyses are carried out for two atmospheric stability conditions: (1) neutral, and (2) stable. Comparisons are made with the corresponding analyses of a comparable conventional single-rotor wind turbine(SRWT) to assess changes in: (a) aerodynamic efficiency, and (b) dynamic loads on the turbines. From results we can conclude that the DRWT improves isolated turbine performance even when atmospheric boundary layer effects are considered. DRWT enhances wake mixing when background turbulence due to the atmospheric boundary layer is moderately high. This has implications on wind plant performance when multiple turbines are placed one behind the other .No significant increase in aerodynamic loads is observed in the DRWT design .In fact, the out-of-plane blade root moment of the main rotor is reduced in the DRWT. Spectral analyses show peaks in unsteady loads at the rotor blade passing frequency and its harmonics for both the primary and secondary rotors. Loads at other (combination) frequencies are observed in the secondary rotor

Keywords: *SRWT, DRWT , Harmonics, Boundary layer*

1. Introduction

Wind power is the use of air flow through wind turbines to mechanically power generators for electric power .A wind resource is one of the clean energy resources and having vast potential that covers more than two hundred times of annual world energy consumption . It is very important to use this wind resource as an energy source for a reduction of fossil fuel dependency and sustainable development. To use the wind resource, a wind turbine that converts wind energy to mechanical energy through rotation of a rotor is used. A worldwide installed capacity of wind turbines has shown a high growth rate because power generation of a wind turbine has lower cost of generation and higher technology maturation than that of other renewable energy resources [3]. To reduce cost of wind energy further and maintain growth of wind power, it is required to improve the energy conversion efficiency of a wind turbine. The energy conversion efficiency of a wind turbine is usually characterized by its power coefficient which is calculated as the ratio of the power extraction from a wind to the power available in the wind.on the basis of classical momentum theory, the maximum power coefficient of a wind turbine having an ideal single rotor without any losses is about 59% which is known as the Betz limit]. Practically it is found that the maximum power coefficient of conventional horizontal axis wind turbines having a single rotor is about 40 to 50% due to some losses such as viscous loss, dimensional loss, and transmission loss. Over the past few decades, different concepts and blade designs of a wind turbine have been proposed to increase the maximum power coefficient. A Dual-rotating wind turbine having two rotors rotating in same or in opposite direction at the same axis has been proposed as a new concept to improve the maximum power coefficient of a wind turbine. classical momentum theory states that Newman found that the maximum power coefficient of a wind turbine having two rotors without any losses was increased to about 64% . Recently, based on the above result, many researches for a counter-rotating wind turbine have been carried out to obtain more power from a wind than a conventional wind turbine having a single rotor.

The most of the wind turbines currently in operation have the conventional concept design. That is a single-rotor wind turbine system which is connected through transmission system (gearbox) to a generator. Recently, the research on dual-rotor wind turbine is under process in several companies and individual researchers have been introduced to the market. It has been accepted that the steady state performance of the dual-rotor wind turbine system for extracting energy is better than the single-rotor wind turbine system . The counter-rotating wind turbine has two rotors rotating in opposite or in same directions on the same axis. It has been proposed on the basis of the theory which states that a configuration of two rotors having the same swept area on the same axis has higher maximum power coefficient than a conventional configuration of a wind turbine having a single rotor. In this paper author has designed of a gearbox of dual rotor wind turbine system. This gearbox composed of both compound and planetary gear train. The wind speed rotates the rotor of wind turbine 60-70 RPM in case of large wind turbines and 100-300 in small wind turbines. The large wind turbine requires efficient gearboxes to convert small rotational speed of 70 RPM to the high rotational speed of 1600-1800 RPM. The Author had designed a gearbox on CATIA which has two input shafts and one output shaft. The dual rotors in front and rear side capture wind energy. The captured wind energy is transformed into high speed rotational energy by transmission system. In this Wind turbine the radius of the wind blades for the dual rotor is taken as 1.5m. The rated speed for the wind turbine is taken 10m/s. Cut in speed is about2.5m/s and Cut out speed is taken 25m/s. Lot of research has been done in application of gearless drive in dual rotor wind turbine but few researches has been done in application of mechanical gearbox in dual rotor wind turbine. .

2. Literature Review

In order to increase the power efficiency of wind turbines on Counter Rotating Wind Turbine research have been carried out by many investigations and also comparison of power output in Counter Rotating Wind Turbine with that of Single rotor wind turbines was reported. The power curve has been obtained experimentally and numerically for a 30 kW Counter Rotating Wind Turbine system and it has also the effects of distance and diameter ratio between two rotors by using Blade Element Momentum (BEM) theory (jung). Appa Energy Systems has measured the rotor performance and numerical predictions using BEM theory for a prototype of 6 kW counter Rotating Wind Turbine . The field by Appa Technology tests conducted in this study demonstrated that power conversion efficiency could be increased by 25 to 40 % by means of a contra rotating rotor system. At low rotor speeds the net power coefficient is found exceed Betz limit of 59%. This might be possible since the two rotors are in different planes having velocity compounding characteristics. Probably the interference effect between two slowly moving rotors seems to be minimal. Therefore there is a need to revisit this test using grid-connected models. Moreover, the buffeting phenomenon that is believed to be resulting from the interaction of the dual rotors was not observed in these tests. The second observation suggests that the contra rotation of two rotors appears to benefit large-scale wind turbines that operate at 15 to 20 rpm .(J.D. Booker) has designed A compact, high efficiency contra-rotating generator suitable for wind turbines in the urban environment design, development and performance testing of a permanent magnet generator for wind turbine applications in urban areas. The radially interacting armature windings and magnet array are carried on direct drive, contra-rotating rotors, resulting in a high torque density and efficiency. This topology also provides improved physical and mechanical characteristics such as compactness, low starting torque, elimination of gearboxes, low maintenance, low noise and vibration, and the potential for modular construction. The design brief required a 50 kW continuous rated prototype generator, with a relative speed at the air-gap of 500 rpm. A test rig has been instrumented to give measurements of the mechanical input (torque and speed) and electrical output (voltage, current and power) of the generator, as well as temperature readings from inside the generator using a wireless telemetry device. Peak power output was found to be 48 kW at a contra-rotating speed of 500 rpm, close to the design target, with an efficiency of 94%. It is anticipated that the generator will find application in a wide range of wind turbine designs suited to the urban environment, e.g. types sited on the top of buildings, as there is growing interest in providing quiet, low cost, clean electricity at point of use[6]. Seungmin Lee has calculated the Effects of design parameters on aerodynamic performance of a counter-rotating wind turbine In this study, a modified blade element momentum theory for the counter-rotating wind turbine is developed to investigate the effects of these design parameters such as the combinations of the pitch angles, rotating speeds and rotors‟ radii on the aerodynamic performance of the counter-rotating wind turbine[7]. Azhumakan Zhamalovich Zhamalov has designed Simulation Model of Two-Rotor Wind Turbine with Counter-Rotation. [2]

3. Experimental Setup and Test Models

a). Atmospheric Boundary Layer (ABL) Wind-tunnel

The present experimental investigations were performed in a large-scale Atmospheric Boundary Layer (*ABL*)wind-tunnel located at the Aerospace Engineering Department of Iowa State University. This wind-tunnel is a closed-circuit wind-tunnel with a test section dimension of 20m×2.4m×2.3m, optically transparent side walls, and a capacity of generating a maximum wind speed of 45 m/s in the test section. Figure 1 shows a picture of the test section of the *ABL* wind-tunnel with a test *HAWT* model mounted in the center of floor. Chains (with spacing of 15inches) that are perpendicular to the flow direction were placed on the upstream floor of the wind turbine model in order to generate a typical atmospheric boundary layer wind profile and turbulence intensity usually seen in off shore wind farms. The wind-tunnel ceiling is flexible and is adjusted along the length to ensure the turbulent boundary layer growth of the simulated *ABL* wind under close to zero pressure gradient condition in the flow direction.

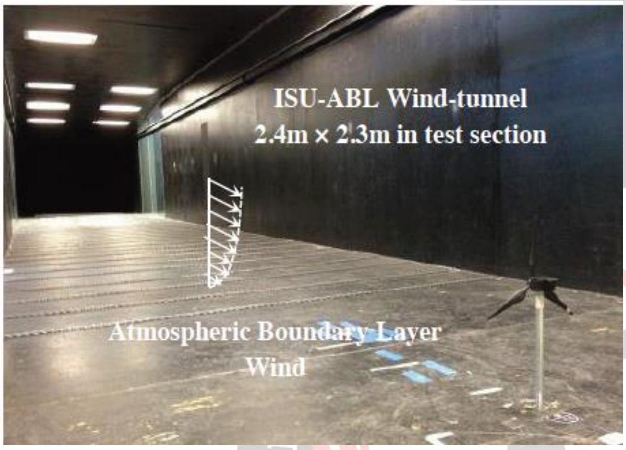
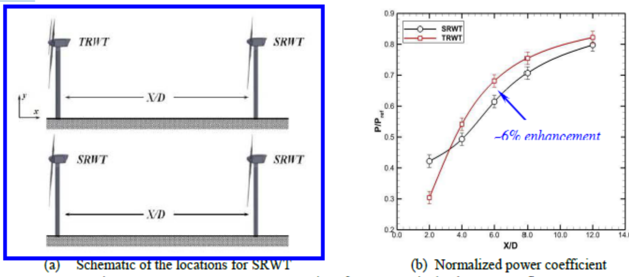


Fig. 1 Power and stream wise velocity comparisons for the wind turbine in downstream

In order to examine if the DRWT model is really better for the velocity recovery in comparison to the SRWT model in the wind turbine downstream, a SRWT was set in the wake flow at variant locations for comparison between these two wind turbine models. The power output coefficient was selected for the comparison which was normalized based on the measured power output for an isolated SRWT. Figure 11 lists the locations where the SRWT was installed in the downstream wake of the SRWT and TRWT respectively for measuring the power output. In the present measurement, the upwind SRWT and TRWT models were running at the optimum operation conditions and the downwind SRWT was first measured at X/D=2, and then was moved downstream until X/D=12. It should be noted that according to the research conducted by Alfredsson et al (1982), the Reynolds number would have significant effects on the power output coefficient. For example, the maximum power coefficient for the miniature wind turbine models operating at low Reynolds number would be much lower than that of the utility scale wind turbines.



(a) Schematic of the locations for SRWT (b) Normalized power coefficient

Figure.11 Power measurement comparison for a SRWT in the downstream flow

A wind tunnel study was conducted to investigate the aeromechanic performance and the wake characteristics of an innovative twin-rotor wind turbine (DRWT) in comparing with those of a traditional single-rotor wind turbine(SRWT). The experimental study was performed in a large-scale wind tunnel with scaled DRWT and SRWT models placed in an Atmospheric Boundary Layer (ABL) wind. In addition to measuring the dynamic wind loads acting on the wind turbine models, a high-resolution PIV system was used to perform both "free-run" and "phase locked" measurements to quantify the flow characteristics and the evolution of the unsteady vortices in the turbine wakes. The dynamic wind loads acting on the model wind turbines were found to fluctuate significantly

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