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[Invited Speaker]

Design and Optimization of Wind Systems through a Systems Engineering Approach

Rick Damiani
National Renewable Energy Laboratory (NREL), USA

Abstract:
The Wind-Plant Integrated System Design & Engineering Model (WISDEM™) was developed at the National Renewable Energy Laboratory to perform system-level nonlinear optimization of wind turbines and wind power plants. Using an integrated model with combined physics and cost modeling capabilities allows for the direct exploration of trade-offs in the design of different subsystems. Through WISDEM researchers can investigate the design space of turbine components while also recognizing the links between balance of station costs and the main environmental design drivers. As such, WISDEM facilitates both the optimization of rotor, tower, substructure, etc., thereby assessing the effects of technology innovations on the rest of the wind plant system, as well as techno-economic studies that reveal the resulting trends in the levelized cost of energy (LCOE). These types of analyses help decision makers plan appropriately for future onshore and offshore wind developments while also demonstrating areas for reliability, performance, and LCOE improvements. This talk presents some specific examples of application of this technology.

MRS using DAWTs for power increase

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Abstract:

In these days, a trend of wind turbine industry is making a wind turbine larger and larger. It is because electric generating capacity of wind turbine depend on wind speed and area it can catch wind. However, scaling up a wind turbine causes unfavorable increase in mass and hence increased cost. To solve these problems, the concept of multi-rotor system (MRS) has been suggested.

Diffuser augmented wind turbines (DAWTs) are wind turbines where the rotor is surrounded by a structure. This structure brings about that air is drawn into the rotor at a higher rate and accelerates more than in the case of a conventional wind turbine. Due to this effect, DAWTs with brimmed diffuser show 2 to 3 fold power increase compared with conventional turbines.

In the present research, DAWTs are studied in a MRS. In wind tunnel experiments and CFD simulations, the power output and drag of two and three DAWTs in MRS is measured, along with the flow around circular disks in the same configurations as the MRS. The wind turbines are setup in side-by-side arrangement and the space between the wind turbines is variable. The power output and drag of DAWTs in MRS was compared with these of stand-alone DAWT. It was found that the power output and drag of DAWTs in MRS are increase dependent on the number of DAWTs and the space between the wind turbines. In the 2 DAWTs configuration, power increase of up to 6% and drag increase of up to 4% was measured with suitable spacing. In the 3 DAWTs configuration, power increase of up to 14% and drag increase of up to 7% was measured with suitable spacing. In comparison, a MRS with conventional wind turbines didn’t show a significant change in power output and drag. The results can be explained by observing the bluff body flow phenomenon in the wake interference around the circular disk.

Re-Powering of Wind Farms: State of Art

Siraj Ahmed Khan and Manoj Verma

Maulana Azad National Institute of Technology

Abstract:

Today the wind energy is experiencing a significant role in fulfilment of the energy needs of the world. Wind turbine technology and design has greatly improved in recent years with the development of megawatt class turbines. The aim of repowering is to generate the highest possible constant output power under all types of wind conditions in India. Re-powering in wind energy means replacement of installed old wind turbines of lower capacity by modern turbines of higher capacity normally in lesser numbers. It also refers to replace first generation turbines installed for more than fifteen years back. It has generally been accomplished by installing fewer, larger capacity turbines. The modern commercial grid connected wind turbines are multi-megawatt machines equipped with advanced operation and control systems. It is the need of the time to improve power generation in developing countries. Wind energy has found favour due to benefits of relativity less installation time, environment friendliness and cost competitiveness. In this paper a detailed study of various performance indices necessary to determine the reliability and performance of a particular wind farm for repowering is studied. To carry-out the study an old wind farm located at Jamgodrani, Madhya Pradesh, India is selected to implement repowering. The wind farm was commissioned in 1990 with a capacity of approximately 10MW, which consists of 45 wind turbines of 225 kW capacity each.

Flow field elucidation of the rotary column with fins and lift enhancement of Magnus windmill

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Abstract:

In the current wind power industry, large propeller type windmill is the mainstream. However, we call on the type of small windmill which is excellent in quietness with high performance. Spiral Magnus is a unique wind turbine system that rotates with cylinders which have spiral-shaped fins coiled around them (instead of using the more common propeller-type blades). When the spiral cylinders catch the wind, rotating force is generated due to the aerodynamic properties caused by the Magnus Effect. Spiral Magnus windmill is generated by a different mechanism from the conventional one. In previous researches, analysis by wind tunnel experiments and computer simulation of the fin shape have been carried out. In addition, a windmill of 20kW and of 11.5m in diameter is operated from 2011, and high power generation performance is shown. According to the actual measurement results, approximately 8% of the generated power is used to rotate the rotary cylinder.

In the field, the power generation amount of this spiral Magnus windmill will be greater than that of the propeller-type wind turbines of the same size because the lift force can be enhanced for the Spiral Magnus windmill.In the flow field around a rotating cylinder, it becomes complicated intertwined various flow.There remains the possibility of improved performance, and it is

important that the mechanism of lift enhancement is elucidated.

The lift can be improved by attaching a fin to the rotating cylinder. In the present study, three models (cylinder with no fins, straight fins and spiral fins) were installed. The PIV system was also used to better understand the flow fields around the cylinder. Fluid force measurements were performed by a strain gauge force balance. Method of visualization is taken with the flow field

around the model using a CCD camera by irradiating a YAG laser.

Considering the results of the experiment, it was confirmed that the aerodynamic performance of the rotating cylinder can be improved by the fin. However, the velocity fluctuation of the straight fin is reaches a relatively far area from the cylinder. The rotary cylinder with the spiral fins was able to generate the greatest lift among three models, because the spiral fin effectively influences the vicinity of the cylinder surface. Further, in the flow field around the fins, the leading edge vortex is generated. We concluded that the leading-edge vortex of the fin was strongly related to the lift force of the rotating cylinder.

Arrangements of three diffuser augmented wind turbines in a multi-rotor system

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Abstract:

Due to the scaling law a wind turbine faces unfavorable increase in mass. The power scales with the rotor diameter squared, whereas the mass increases with the rotor diameter cubed. A known concept to overcome this issue is the multi-rotor concept. It comprises more than one rotor in a single structure. Concepts of multi-rotor systems (MRS) have appeared and disappeared several times in history. One of the biggest wind turbine installed to date is the Vestas V164-8.0 MW with a rotor diameter of 164 m. Denmark based Vestas is the biggest manufacturer of wind turbines in the world and they recently started research on a four-rotor system to test dynamics of the rotors and loads on the structure.

Diffuser augmented wind turbines (DAWTs) are wind turbines where the rotor is surrounded by a structure that increases the mass flow through the rotor plain and hence leads to increased performance. In this research DAWTs with brimmed diffuser are used which have achieved 2 – 3 fold power increase. Although DAWTs showed high rotor efficiency, they have not seen commercial success yet.

In the presented research DAWTs are arranged as a multi-rotor system. In wind tunnel experiments the power output of three DAWTs in MRS configuration is measured. The three wind turbines are setup in various angles between the side-by-side (180°) and a triangle (60°) arrangement. The second variable in the experiment is the spacing between the wind turbines. The average power output of a MRS was compared with the single turbine power. It was found that the power output of DAWTs in a MRS increases or decreases dependent on the angle of arrangement and the space between turbines. Power increase of up to 9 % was measured in the side-by-side arrangement with suitable spacing. Power decrease of 4% was observed for the triangle arrangement in the closest spacing of DAWTs. In comparison, a MRS with conventional wind turbines didn't show a significant change in power output at any arrangement or spacing. We can conclude that there is a great potential to use DAWTs in MRS. With suitable arrangement and spacing of DAWTs increased power output can be achieved.

Air Borne Wind Energy Generation on Tethered System

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Abstract:

Tethered system is proposed for air borne wind energy generation utilizing high and steasy wind power over the canopy of ground wind boundary layer. The system is to place the heavy electricity generator and place a windmill upward in the high altitude sky. The straight brade windmill is employed for the windmill and constructed to be light in weight made by new advanced material engineering as CFRP. Wind energy generated by the wind mill in high altitude is transferred to the generator placed on the ground employing tether technology.

Specifcations for the wind energy generation are (Altitude 50m, Average wind velocity 6m/s, nominal wind velocity 12m/s, and cut wind velocity 20m/s, Estimated electricity 1Kw/m2, efficiency 25％, effective electricity 0.25KW/m2).

The plan of the development is as follows;

1.Small wind-tunnel model: windmill diameter 0.16m×span0.2m×2＝0.016KW

2.Large wind tunnel model: windmill diameter 0.6m×span0.6m×2＝0.2KW

3.Demonstration model: windmill diameter 1.3m×span1.3m×2＝1KW

4. Practical model: windmill diameter 6m×span6m×2＝20KW

The plan is now in the phase 2 to test in wind tunnels and to demonstrate in field and also in the phase 3 for performance estimation of the windmill employed with wind tunnel data.

Results will be presented at the conference accompanied with recent wind tunnel experimental results and numerical simulation.

Optimum Design Configuration of Ribbon Wheel Type Wind Turbine

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Abstract:

Ribbon wheel type wind turbines, can be easily fabricated from cheap and locally available materials. It is not only used for effective education of renewable energy such as wind power generation but also for utilization as power source in least developed Countries. Previous study on ribbon wheel type wind turbine has been reported by Motohashi et al. [1]. In that study they investigated the effects of twisting angle, number of blades, solidity and the influence of installation location of blades in their width.

Until now, there has been no further systematic work to on the optimum design configuration of the ribbon wheel type wind turbines. In order to determine the optimum design configuration for maximum power coefficient, we fabricated the test rotors with various shapes and carried out the experiment in the wind tunnel.

Furthermore, not only solidity and number of blades were investigated but also the impact of twisting angle and blade shape were considered.

The tested rotors were standard type, front-cutting type, back-cutting type and combined front and back-cutting type. The solidity ranges of the tested rotors were from $\sigma = 0.22$ to $\sigma = 0.66$

We carried out a wind tunnel test in order to investigate the power characteristics of the different rotor shapes. The wind velocity was changed from 4 to 10 m/s in the wind tunnel. Then the rotational speed N and torque Q were measured at each wind velocity respectively. λ, CQ and CP were calculated by using N and Q.

Four blades gave higher CP than two blades for a given solidity of ribbon-wheel with the highest CP at solidity $\sigma = 0.44$.

By cutting the frontal area CPmax improved from 0.19 to 0.20. By cutting both the frontal and back area CPmax improved from 0.19 to 0.23. However, by cutting the back area only, CPmax was reduced from 0.19 to 0.15.

Power coefficient of ribbon wheel type wind turbine can be optimized by changing the cutting shape and the cutting position on the blade. From these results it was proved that, front-cutting and combined front and back-cutting had improved the power coefficient by 5% and 21% respectively. Additionally, a ribbon wheel type wind turbine with maximum power coefficient is technically viable for utilization as a power source for various applications in least developed countries.

References 1) H. MOTOHASHI and S. Tan, "Blade Shape Effects on Power Characteristics of Ribbon Type Wind Turbine"(in Japanese), Journal of Japan Wind Energy Association, Vol35(2011), No.2, pp120-125