INTERNATIONAL JOURNAL OF ADVANCE RESEARCH, IDEAS AND INNOVATIONS IN TECHNOLOGY

ISSN: 2454-132X
Impact factor: 4.295
(Volume 4, Issue 2)
Available online at: www.ijariit.com

Performance analysis of wind turbine using wind lens technology

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ABSTRACT

Wind power generation is proportional to the third power of the wind speed as per available thesis and mathematics. Wind energy is converted into electricity using wind turbine. According to the present design available of wind turbine, only 50% of kinetic energy of wind is converted into useful power output. If we are able to concentrate more wind energy over the turbine blade then the power output of wind turbine can be increased effectively. To embody this, scenario, a simple brimmed ring structure which intentionally creates turbulence behind the turbine blade to draw more air flow into the turbine is added externally at the periphery of the blade. This structure effectively increases the speed of the wind turbine leading to higher energy output from the wind turbine.

Keywords: *Wind turbine, Wind lens, the turbine blade.*

1. INTRODUCTION

Wind is a renewable form of energy generated because of uneven heating of earth surface due to solar radiation. Electricity can be generated by converting the kinetic energy of wind by using wind turbine. The wind turbine was made to produce energy for a clean and safe environment. With the increasing population and the economic development, the demand for energy is increasing notably. However, the limitation of fossil energy and the environmental problems caused by burning the fossil energy are becoming increasingly severe, which arouses the attraction to various types of renewable energies, such as solar energy, wind energy, biomass, etc. Among these types of renewable energies, wind energy is one of the most important ones.

In recent years, wind energy has been developed rapidly for it is environmental friendly and renewable. The statistical data shows that the global installed capacity of wind turbines has kept increasing in the past ten years. The annual installed capacity of the wind turbines for 2015 is 63 GW, which increases by 22% compared with the one for 2014. Wind energy is extracted by wind turbine and transformed into electricity. Previous study has found that the power output of the wind turbine is proportional to the third order of the wind speed. Therefore, a slight augmentation of the wind speed can lead to notable increment of the power output. It was proved that a flanged diffuser adding around the rotor of the wind turbine, known as the wind lens, was able to increase the wind speed at the rotor significantly, and increase the power output of the wind turbine notably. Experiments and numerical simulations were carried out to study the efficiency of the wind lens. Ohya tested the power output of the wind turbine with wind lens and then compared it with bare wind turbine. The power output was found to be increased by 2-5 times after adding the wind lens to the wind turbine. According to the wind tunnel and field experiments, Gilbert et al. found that the power output was increased by 4 times with diffuser device. Abe and Ohya investigated the flow field around the diffuser pipe experimentally. The results indicated that the pressure at the exit of the diffuser was lower than that at the upstream, while the velocity at the entrance of the diffuser was higher than the incoming wind speed. PIV image by Ohya showed that the air at the entrance was drawn into the wind lens because of the pressure difference, which increased the flow rate inside the wind lens. The effect of the flange was investigated by Abe. The experimental data demonstrated that the velocity inside the wind lens with the flange was remarkably larger than that without the flange. From the available data we found that the acceleration performance is directly proportional with the length of the wind lens. Ohya have carried out various experiment to understand the relation of the wind turbine energy output and the turbine blade parameters. The results of his experimental data showed that arc and cycloid presented better performance.

The same conclusion can also be found in the study of Amer. Based on the experimental results by Ohya, a wind lens with smaller dimension and higher output was proposed which was called compact wind lens.

The investigations on wind lens design in recent survey are mainly based on several existing typical profiles. The wind lens profile is far from optimal. Besides, the existing studies mainly focus on the increase of power output, ignoring the drag force on the wind lens exerted by the moving air. The drag force usually increases as the wind speed, which results in more cost of the wind lens. Therefore, an effective optimization method for the shape design of the wind lens should be developed, both regarding to velocity increasing and wind load decreasing.

2. WORKING OF WIND TURBINE

The moving air or wind contains the kinetic energy due to its motion. When the wind blows toward the turbine's rotor blades, the energy conversion takes place when wind strikes on the blades due to the profile of the blades and rotors spin around slowly, capturing some of the kinetic energy from the wind. The kinetic energy of wind is converted into mechanical energy in form of rotation of rotor blades and rotor shaft. The rotor blades are connected to a rotor shaft and rotor shaft is further connected to a gearbox. The unit consisting of shaft, gearbox and generation located behind the turbine blades is known as nacelle. The gearbox is a step-up type which converts the low-speed rotation of the rotor shaft into high-speed which drive the generator efficiently. The generator, immediately behind the gearbox, converts the mechanical energy of the gearbox output shaft into electrical energy.

Anemometer and wind vanes are also provided on the nacelle. Anemometer measures the wind speed. In case of a very high wind speed, more than 15 m/s, the wind turbine is cut-off from the gearbox and generator to avoid the mechanical damage. A wind vane analyzes the direction of the wind and in case of change in wind direction, it gives signals to yaw motor and rotate the wind turbine axis accordingly.

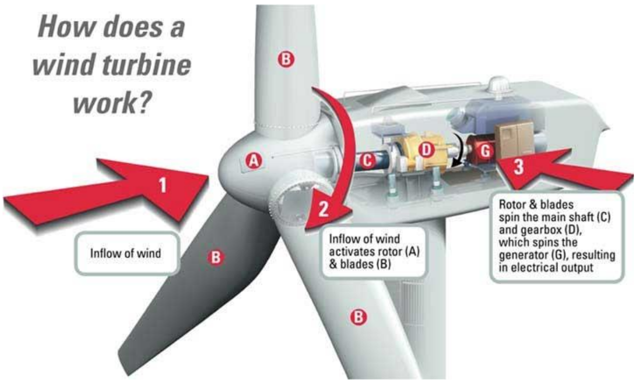

Figure 1. Working of wind turbine

The electric current produced by the generator can be transmitted to the electricity grids. The electricity flows through a cables running down through the inside of the turbine tower to the substation. From this substation the voltage of the electricity can be transmitted efficiently for household use to nearby communities.

3. WINDLENS

A wind lens is a modern type of wind power system which consists of a simple brimmed ring structure that surrounds the rotor blades. The brimmed ring structure is known as a "Wind Lens". The wind lens causes a low pressure area behind the rotor blades which causes more air to pass through the turbine, this, in turn, increase the rotor blades rotation speed thus increases the energy output of the wind turbine.

Figure 2. Wind-Lens

Due to wind lens, air flow gets disturbed around the periphery and turbulence is generated. This creates a low pressure zone behind the wind turbine blades, causing more wind to pass through the turbine blade. This increases the blade rotation, in turn increases the turbine rotor shaft speed (RPM) and ultimately, the power output.

4. METHODOLOGY

- Design of Blades / Proper selection of suitable blades.
- Analysis of horizontal axis wind turbine.
- Design of Wind-lens
- CFD Simulation using Ansys/Solidworks.
- Fabrication and Manufacture a Prototype
- Performance analysis of wind turbine with and without wind-lens.

5. DESIGN / SELECTION OF WINDLENS TURBINE BLADE

Aerofoil Profile:

A number of wind turbine aerofoil's are available in different series suited for different application. National Advisory Committee for Aeronautics (NACA) have designed and developed a series describing the aerofoil profile of the blades. The profile of the NACA aerofoils is described using a series of digits following the word "NACA" which explains the camber, chord length, angle of attack and other parameters. NACA-6 series has the following advantage,

1. High maximum lift coefficient
2. Very low drag over a small range of operating conditions
3. Optimized for high speed

Adding to the above advantages these series are easy to handle and are efficient. NACA- 6(3)-215 series is chosen.

Material

The kinetic energy of the wind is energy is converted into mechanical energy by the rotation of wind turbine's rotor blades. Since ancient days, wood is the most widely use material for the rotor blades. In the modern day technology wood is replaced by modern materials such as glass fiber reinforced plastic (GFRP), carbon fiber reinforced plastic (CFRP), steel and aluminum.

Calculations / Dimensions

Turbine power output (P),

$$P=0.5*\rho*A*V^{3*}C_p$$

Where,
P=Power output from turbine (W), in this case wind turbine design for 30 W for study purpose.
ρ=Density of air (kg/m^3), 1.225 kg/m^3
A= area swept by rotor (m^2)
V=velocity of air (m/sec), 6 m/s
C_p=power coefficient, 0.59

Thus, using above values and formula

$P=0.5*\rho*A*V^{3*}C_p$
$30=0.5*1.225*A*6^3*0.59$
A=0.3629
D=0.680 m, i.e 680 mm. This is the wind turbine rotor diameter.

Clearance between wind lens and rotor blade:
h=10mm (constant) – mostly preferred valve.

Wind lens throat diameter:
D_w = D+2h =680+20 = 700 mm

Length of Wind lens:
L_t/D_w=0.221
L_t = 154 mm

Height of Wind lens:
h_L = 0.1*D_w = 68 mm

Sample Design and proto-type Model:

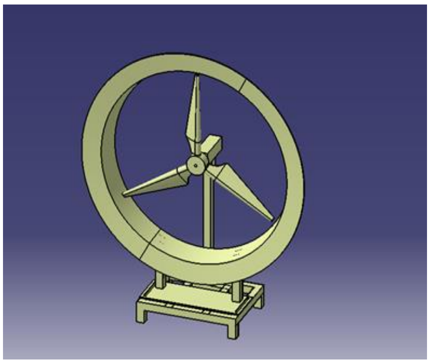

Figure 3. Sample Design in CATIA

6. EXPERIMENT RESULT

The performance of wind turbine is analyzed by comparing the power output or rotor shaft speed obtained with and without using wind-lens at various input parameter air velocity. The experimental analysis is carried out and the output result table is shown below:

Sr. No	Air Velocity (m/s)	Speed of Rotor Shaft of Wind Turbine (RPM)	
		Without Wind-Lens	With Wind-Lens
1	4	90	105
2	4.5	100	106
3	5	112	124
4	6	130	148

Thus it is observed from the above results that the power output of the wind turbine increases 8% to 15% by using wind lens technology.

7. CONCLUSION

In this project paper following points we concluded:

- The energy output of the wind turbine can be increased by using wind lens technology by about 20-25% times.
- However wind lens require a high initial investment, more research more is needed for low cost manufacturing of win lens.

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