Increasing The Theoretical Power Coefficient of A Vertical Axis Wind Turbine Using Novel Mantle Nozzle

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Abstract - Many researchers are working to commercialize miniature vertical axis wind turbines (VAWT) by building an efficient, economical and perfect one to use for residual energy production especially in urban areas. The purpose of this paper is to present a vertical axis wind turbine with a novel structure which will produce decent convergent effect in such a way to step up the wind velocity that is about to reach the rotor of vertical axis wind turbine. Using of the convergence effect given by the novel structure, the wind turbine can be readily used in low wind speed areas. Though the structure used in the present investigation has not been optimised, but a sincere effort has been made to analyse the structure dimensions for better performance of the system. This design of structure will increase the velocity of wind that is reaching the wind turbine which would in turn increase the power output of wind turbine. Apart from the augmentation of wind velocity the structure also helps in reducing the maintenance cost of wind turbine in various ways and hence would attract entrepreneurs.

Keywords: novel nozzle structures, theoretical power of wind velocity.

INTRODUCTION

Wind is nothing but the movement of air from high pressure areas to low pressure areas. As air is moving it consists of energy and this energy is used to produce power.

Mankind has been harvesting the power of the wind for thousands of years. Firstly we used it to help in crushing of grains. We then discovered how to harness the wind's energy to propel our ships, grind wheat, pump water etc. In the 20th century, we discovered how to harness the wind energy to produce electricity. The first wind turbines were built. Now as the world tries to wear itself from fossil fuels, as an energy source wind turbines are one of the tools we are relying on to provide clean and unlimited energy.

A wind turbine readily accepts kinetic energy of wind, as it hits the propellers and converts into electricity. A wind turbine is quite simple in design consisting propellers, shaft, generator. The propeller catches the wind and helps to rotate the shaft. The turning of the shaft helps to transmit power to the generator and creates electricity.

HAWT is most popular and widely used type of wind turbine. Companies such as Vestas, Siemens and GE develop and deploy HAWTs around the world making them the largest and most flourishing wind turbines. Backing these companies is rock solid wind turbine technology. All major wind farms around the world employ HAWTs to aid in the generation of electricity for small towns and large cities.

The design and manufacturing of HAWT blade is complex as the blade is tapered and twisted with varying cross-section in order to achieve optimum aerodynamic performance.

Recently VAWTs have been gaining popularity due to interesting personal greenery solutions. Small companies all over the world have been marketing these new devices such as Helix wind, Urban Green Energy and Wind spine. VAWTs target individual homes, farms, small residential

areas as a mode of providing local and personal wind energy. This reduces the target individual's dependence on external energy resources and opens up a whole new market in alternative energy technology.

Advantages of VAWT over the HAWT

- It can be mounted on ground itself and hence it is effective for generating power
- Investment cost is low
- It doesn't require tall supporting structure, simple design and cost reduction.
- Most of VAWTs main generator structure is built primarily on ground level. This factor makes the day to day maintenance and repair less complicated and thus less expensive.
- Since they are closer to ground, these turbines are more bird-friendly, so they don't destroy wildlife.

The main limitation of vertical axis wind turbine is due to its vertical design, less wind speed is readily available to harness, which eventually means there is less production of electricity.

POPULAR TYPES OF VAWT

- Darrieus wind turbine (egg beater)
  This was by georges darrieus in 1931. It is a high speed, low torque machine that generates alternating current (AC) electricity. Due to low starting torque, it needs some external power source to start the two vertical blades.

- Savonius wind turbine:-
  It is a much slower rotating high torque machine that has two or more scoops. Most wind turbines generally use a aerofoil-shaped blades to drive the rotor, but the savonius wind turbine actually uses drag and thus not able to rotate faster than the approaching wind speed. This type of VAWT needs to be started manually. These are major disadvantages in using this turbine and that is the fact it requires more cost and is less efficient than the Darrieus turbine.

VAWT are being used in today's wind farms, so they could generate the renewable energy from the ever present wind.

The device itself is relatively simple with the major moving component being the rotor, the more complex parts like the gearbox and generator are located at the base of the wind turbine. This makes initially a VAWT, a painless undertaking and can accomplish quickly.

Objectives

The main objective of present work is to enhance the velocity of wind turbine by using a novel nozzle structure, and there by power will also be augmented. To accomplish this, an appropriate structure of nozzle has to be fabricated. Hence the performance of laboratory model of VAWT can be determined using nozzle system. The first ever duct type turbine was innovated by Lilley et al. [1]. Mantle nozzle is firstly used by Frankovi et al. [2]. Comprehensive investigations are conducted by Touryan et al. [3], Macpherson et al. [4] and New man [5] on vertical axis wind turbine to increase the power coefficient using nozzle system. Satyanarayana et.al. [6], Yogi Manash Reddy [7] worked on horizontal axis wind turbine to increase the power coefficient using nozzle system both theoretically and experimentally.

The fundamental theory of design and operation of wind turbine is derived based on a first principle approach of conservation of energy and conservation of mass in the wind stream. Early in the days of wind turbines, the efficiency of a VAWT was first designed or derived by a German Engineer Albert Betz [8] in 1919. The theory that is developed applies to both horizontal and vertical axis wind turbines. According to Betz, the maximum amount of wind kinetic energy available in the wind that a turbine can extract is 69.3%. This is a pretty strong statement to make considering most turbo machinery exceeds this limit. However, Betz

derived this limit under the assumption of an ideal wind turbine (frictionless and produces no rotational component of velocity) using simple one dimensional momentum theory. But in reality it's not possible.

Wind turbines the generic name which is used for machines with rotating blades net convert kinetic energy of wind into useful power.

EXPERIMENTAL SETUP

The experimental setup consists of wind tunnel, laboratory model wind turbine, nozzle system. Wind tunnel produces wind at a speed of 8.5 m/sec. A rotating disc type anemometer is used to determine air velocity. A non contacting type tachometer is used to measure speed of driver and driven pulleys. Instruments that are used in the study are calibrated. In present study 3 bladed laboratory model VAWT is used.

EXPERIMENTAL PROCEDURE

The theoretical efficiency of lab model wind turbine is determined with and without nozzle systems. Here in each module, the blades of turbine are oriented at angles 0^0, 45^0, 90^0. The wind turbine is placed in front of wind tunnel in such a way that air at high speed has to be focussed on the rotor of the turbine. Wind turbine is placed at a distance of $1\frac{1}{2}$ foot from the wind tunnel. Air from the wind tunnel causes the wind turbine to rotate. As the wind turbine is placed close to the wind tunnel, due to the high turbulence the blades may damage and the turbine is placed away from the wind tunnel, air may not focus on to the rotor. So by trial and error method it is found that the turbine rotates at more speed if it is at distance of $1\frac{1}{2}$ foot from the wind tunnel.

Schematic arrangement of the module M0 and M1 are shown in figure 1 and figure 2 respectively. The convergent nozzle is assembled separately to M1 module. Wind turbine may suffer severe stresses if the nozzle system is assembled to it. Air from wind tunnel is allowed to pass through the nozzle.

Table 1 Investigation for Module M0 (without Nozzle System)

α	T (^{0}C)	i) m/sec	e) m/sec
0	26.80	8	8
45	27.00	8	5.8
90	26.80	8	6.9

Table 2 Investigation for Module M1 (with Nozzle System)

α	(^{0}C)	) m/sec	e) m/sec
0	6.80	10.8	10.8
45	6.90	11.1	7
90	6.90	11	8

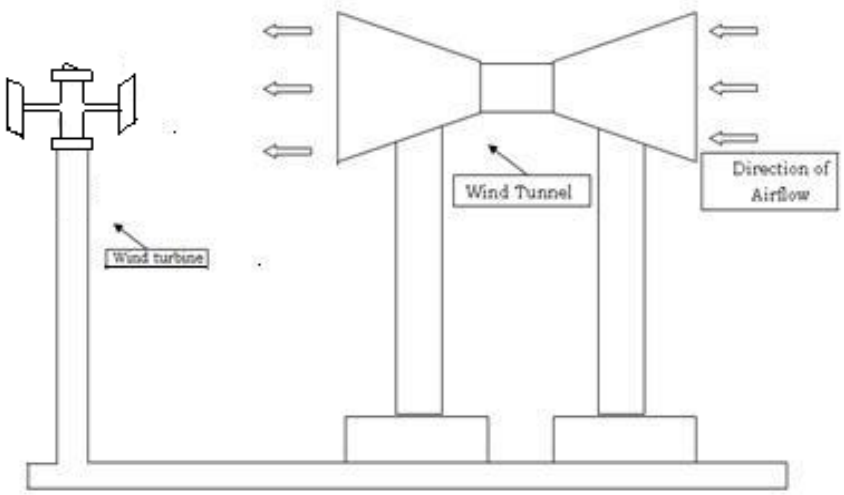

Figure 1 Module M0 (without nozzle)

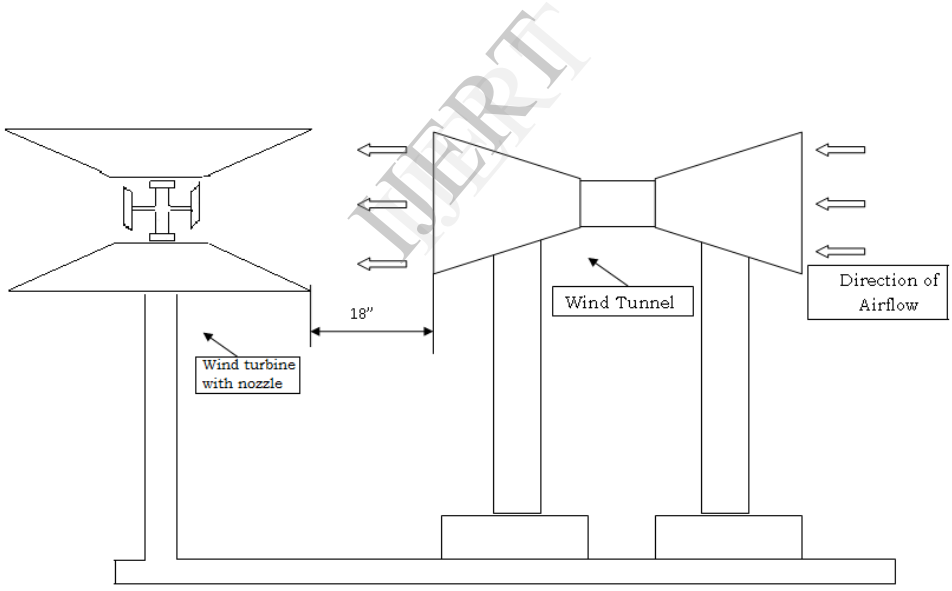

Figure 2 Module M1 (with convergent nozzle)

RESULT: Experiments were conducted at different blade angles at 0^0, 45^0, 90^0 in the quarter segment of a circle it is found that installation of nozzle to the wind turbine has enhanced the wind velocity and the results are tabulated in Table 1 and Table 2.

Graphical representation in figures 3 and 4 illustrates the rise in wind velocity with nozzle system. The effective utilization of kinetic energy of air is occurred at 45^0 of attack.

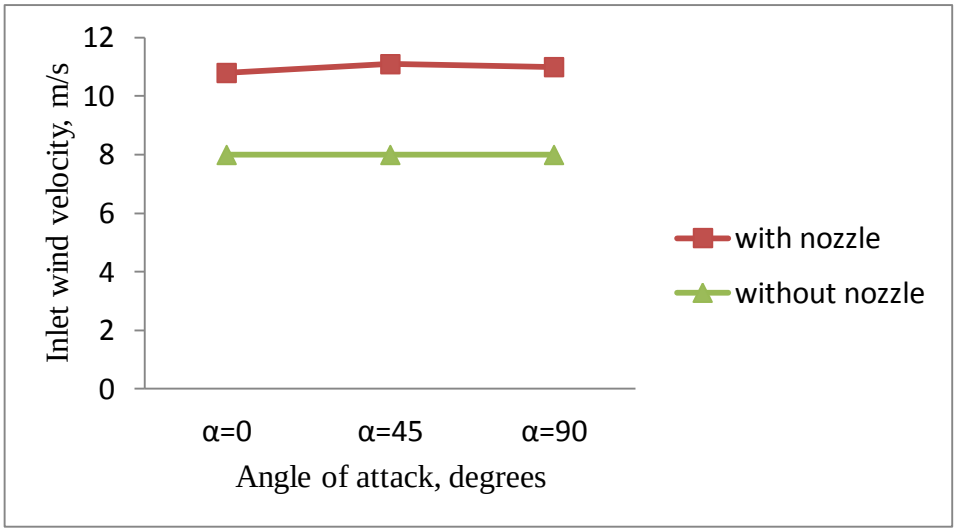

Figure 3. Angle Of Attack Vs Inlet Wind Velocity

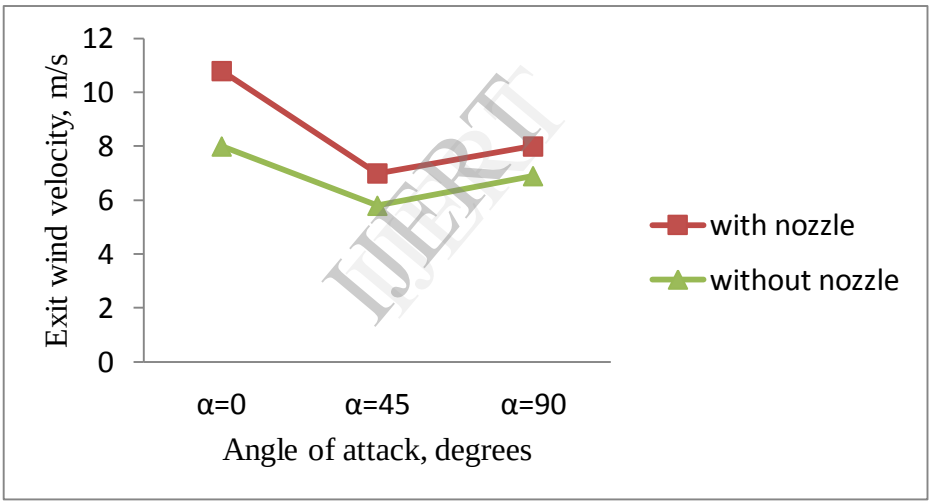

Figure 4. Angle Of Attack Vs Exit Wind Velocity

CONCLUSION

From the investigation it has been proved that at 45^0 angle of attack the wind velocity has increased from 7.5 to 13.2 m/s on installing the novel mantle nozzle system. It was concluded that efficiency of wind turbine increases.

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