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Experimental work on horizontal axis PVC turbine blade of power wind mill

Prof. H. S. Patil,
Associate Professor, Department of Mechanical Engineering,
Vadodara Institute of Engineering, Kotambi, Vadodara- 391510, India
hspatil12@rediffmail.com, hspatil28@gmail.com

Abstract:
Growing concern for the environment degradation has led to the world's interest in renewable energy sources. Wind energy is rapidly emerging as one of the most cost-effective forms of renewable energy with very significant increases in annual installed capacity being reported around the world. The favoured form of turbines used for electricity generation purposes is the Horizontal Axis Wind Turbine (HAWT) with low solidity ratio (ratio of blade area to swept area) and high tip speed ratio, $\lambda = \Omega R/V$wind, where R is the radius of the blades and Vwind is the wind velocity. This type of turbine has a high efficiency or coefficient of performance (Cp), but relatively low torque. Wind energy is kinetic energy associated with the movement of atmospheric air. Wind energy systems for irrigation & milling have been in use since ancient times & since beginning of 20th century it is being used to generate electric power. Windmills for water pumping have been installed in many countries particularly in the rural areas. Wind turbines transform the energy in the wind into mechanical power, which can then be used directly for grinding etc. or further converting to electric power to generate electricity. Wind turbines can be used singly or in clusters called 'wind farms'. Small wind turbines called aero-generators can be used to charge large batteries. Five nations –Germany, USA, Denmark, Spain & India account for 80% of the worlds installed wind energy capacity. Wind energy continues to be fastest growing renewable energy source with worldwide wind power installed capacity. India ranks 5th in the world with a largest wind power capacities which have been established in commercial projects. In India the states Tamilnadu & Gujarat lead in the field of wind energy. There about a dozen wind pumps of various designs providing water for agriculture & domestic purposes all scattered over the country. Today India is a major player in global wind energy market. The present work was originally devised as a student project to examine the possibility of developing a small scale, high torque, self-starting HAWT for applications such as water pumping. In the following we outline the development of the concept of the PVC type HAWT, the development of a experimental setup of the device that includes the design, manufacture, commissioning and preliminary testing of the device

Keywords: Horizontal axis wind turbine (HAWT), PVC blade material.

1. Introduction

The development of wind power in India began in the 1990s, and has significantly increased in the last few years. Although a relative newcomer to the wind industry compared with Denmark or the US, India has the fifth largest installed wind power capacity in the world (World Wind Energy Report 2008). In 2009-10 India's growth rate was highest among the other top four. As of 31 March 2011 the installed capacity of wind power in India was 14550MW (http://panchabuta.com). It is estimated that 6,000 MW of additional wind power capacity will be installed in India by 2012. Wind power accounts for 6% of India's total installed power capacity, and it generates 1.6% of the country's power. India has maintained its position as one of the leading wind power nations, remaining at fifth position worldwide in terms of cumulative installations in 2011. The Indian wind industry has successfully weathered the economic slowdown encountered by many other nations and is moving towards achieving maturity. Presently, the country has a cumulative installed capacity of 15,567 MW. The capacity addition for financial year 2011-12 is expected to be around 3,000 MW, out of which 1,411 MW has already been achieved. According to WISE estimates, the annual capacity increase for the Indian wind market is expected to reach 5000 MW by 2015. The utilization of the energy in the winds requires the development of devices which convert that energy into more useful forms. This is typically accomplished by first mechanically converting the linear velocity of the wind into a rotational motion by means of a windmill and then converting the rotational energy of the windmill blades into electrical energy by using a generator or alternator. For purposes here, we can thus view the windmill as a mechanical device for extracting some of the kinetic energy of the wind and converting it into the rotational energy of the blade motion. This is accomplished, in detail, by having the blades oriented at some angle to the wind so that the wind blowing past the blades exerts an aerodynamic force on them and there by cause them to rotate.

2. Wind Power Technology

Wind has considerable amount of kinetic energy when blowing at high speeds (Patel, 1999). This kinetic energy when passing through the blades of the wind turbines is converted into mechanical energy and rotates the wind blades (Burton et al., 2001) and the connected generator, thereby producing electricity. A wind turbine primarily consists of a main tower, blades, nacelle, hub, main shaft, gearbox, bearing and housing, brake, and generator (Spera, 1994). The main tower is 50-100 m high. Generally, three blades made up of Fiber Reinforced Polyester are mounted on the hub, while in the nacelle the major parts are housed. Under normal operating conditions the nacelle would be facing the upstream wind direction (Patel, 1999). The hub connects the gearbox and the blades. Solid high carbon steel bars or cylinders are used as main shaft. The gearbox is used to increase the speed ratio so that the rotor speed is increased to the rated generator speed (Burton et al., 2001); it is the most critical component and needs regular maintenance. Oil cooling is employed to control the heating of the gearbox. Gearboxes are mounted over dampers to minimize vibration. Failure of gearbox may put the plant out of operation for an entire season as spares are often not available. Thus, new gearless configurations have become attractive for wind plant operators. Modern turbines fall into two basic groups: horizontal axis turbines and vertical axis turbines as shown in Figure 1. Horizontal axis turbines resemble airplane propellers, with two to three rotor blades fixed at the front of the tower and facing into the wind. This is the most common design found today, making up most of the large utility-scale turbines on the global market. Vertical axis turbines resemble a large eggbeater with rotor blades attached vertically at the top and near the bottom of the tower and bulging out in the middle.

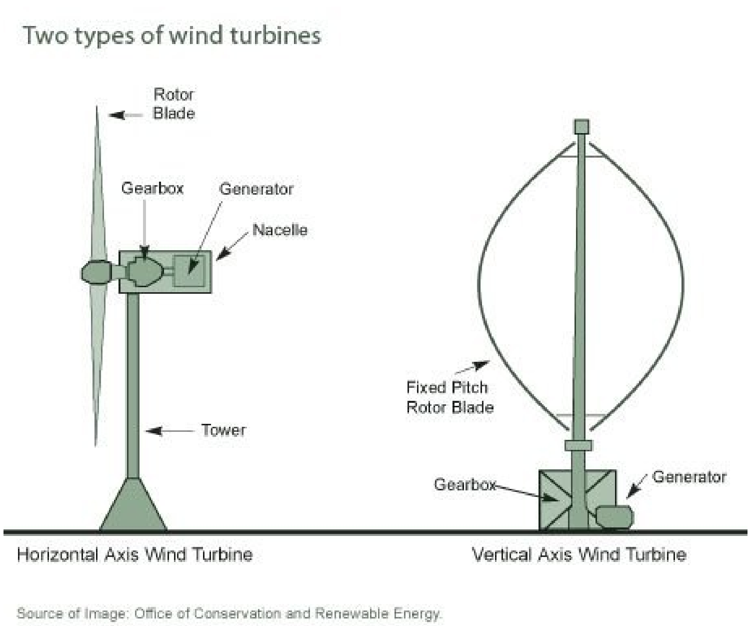


Figure1. Schematic of the horizontal and vertical axis wind turbine (Source: www.centreforenergy.com)

The most dramatic improvement has been in the increasing size and performance of wind turbines. From machines of just 25 KW, twenty years ago, the commercial size range sold today is typically from 600 up to 2,500 KW with 80m diameter rotors placed on 70-100 m high towers. In 2003, the German company Enercon erected the first prototype of a 4.5 MW turbine with a rotor diameter of 112m. Wind turbines have a design lifetime of 20-25 years, with their operation and maintenance costs typically about 3-5% of the cost of the turbine. For the share of different Wind turbine power production facilities

(10MW and greater) refer Table 1. At present, efforts are being made to develop a low cost, indigenous, horizontal axis Wind Energy Generator (WEG) of 500 KW rating. The WEG will have a two bladed rotor and the tower will be a tubular tower with guys. The organizations contributing in the development of the WEG are (i) National Aerospace Laboratory (NAL), (ii) Structural Engineering Research Centre (SERC), (iii) Sangeet Group of Companies, and (iv) Center for Wind Energy Technology (C-WET). It will be specially suited for Indian wind conditions i.e. relatively low wind speeds and dusty environment. It is further learnt that this WEG may cost almost 50% as compared to the other WEGs of the same rating commercially available in India. The WEG is nearing completion and likely to be completed by April-2007 (www.windpowerindia.com).

Table1 Manufacturers-wise wind electric generators installed in India as on Nov.2010 (Resource: http://www.eai.in/ref/ae/win/win.html. Retrieved 2010-11-27)

Power Plant	**Producer / Location**	**State**	**Capacity (MW)**
Vankusawade Wind Park	Suzlon Energy Ltd. / Satara Dist.	Maharashtra	259
Cape Comorin	Aban Loyd Chiles Offshore Ltd. /Kanyakumari	Tamil Nadu	33
Kayathar Subhash	Subhash Ltd. /Kayathar	Tamil Nadu	30
Ramakkalmedu	Subhash Ltd./ Ramakkalmedu	Kerala	25
Muppandal Wind	Muppandal Wind Farm/ Muppandal	Tamil Nadu	22
Gudimangalam	Gudimangalam Wind Farm/ Gudimangalam	Tamil Nadu	21
Puthlur RCI	Wescare (India) Ltd./ Puthlur	Andhra Pradesh	20
Lamda Danida	Danida India Ltd./ Lamda	Gujarat	15
Chennai Mohan	Mohan Breweries & Distilleries Ltd./ Chennai	Tamil Nadu	15
Jamgudrani MP	MP Windfarms Ltd./ Dewas	Madhya Pradesh	14
Jogmatti BSES	BSES Ltd./ Chitradurga Dist	Karnataka	14
Perungudi Newam	Newam Power Comp.Ltd./ Perungudi	Tamil Nadu	12
Kethanur Wind	Kethanur Wind Farm/ Kethanur	Tamil Nadu	11
Hyderabad APSRTC	Andhra Pradesh State Road Transport Corp./ Hyderabad	Andhra Pradesh	10
Muppandal Madras	Madras Cements Ltd./ Muppandal	Tamil Nadu	10
Poolavadi Chettinad	Chettinad Cement Corp. Ltd./ Poolavadi	Tamil Nadu	10

Shalivahana Wind	Shalivahana Green Energy. Ltd./ Tirupur	Tamil Nadu	20.4

3. Potential of Wind Power Projects in India

Wind in India are influenced by the strong south-west summer monsoon, which starts in May-June, when cool, humid air moves towards the land and the weaker north-east winter monsoon, which starts in October, when cool, dry air moves towards the ocean. During the period March to August, the wind is uniformly strong over the whole Indian Peninsula, except the eastern peninsular coast. Wind speeds during the period November to March are relatively weak, though higher winds are available during a part of the period on the Tamil Nadu coastline. In order to tap the potential of wind energy sources, there is a need to assess the availability of the resources spatially. In 1985 a Wind Resource Assessment Programme was taken up in India (Jagadeesh, 2000) around 1150 wind monitoring / mapping stations were set up in 32 states and Union Territories (UTs) for this purpose. A notable feature of the Indian programme has been the interest among private investors/developers in setting up of commercial wind power projects. The gross potential is 48,561 MW (Source C-WET) and a total of about 14,158.00 MW of commercial projects have been established until March 31, 2011. The break-up of projects implemented in prominent wind potential states as on 31st March2011 is as given below in table 2, (Resource http://www.inwea.org/aboutwindenergy.htm)

Table-2 Wind Potential States of India

State-Wise Wind Power Installed Capacity In India		
State	**Gross Potential (MW)**	**Total Capacity (MW) till 31.03.2011**
Andhra Pradesh	8968	200.2
Gujarat	10,645	2175.6
Karnataka	11,531	1730.1
Kerala	1171	32.8
Madhya Pradesh	1019	275.5
Maharashtra	4584	2310.7
Orissa	255	-
Rajasthan	4858	1524.7
Tamil Nadu	5530	5904.4
Others	--	4
Total (All India)	48,561	14,158

Out of 540 wind monitoring stations over 200 stations in 13 States and UTs with annual mean wind power density greater than 200 W/m2 at a height of 50 m above the ground level show wind speeds suitable for wind power generation (MNES, 2006). The wind power density at a height of 50m above the ground level is depicted in Figure 2.

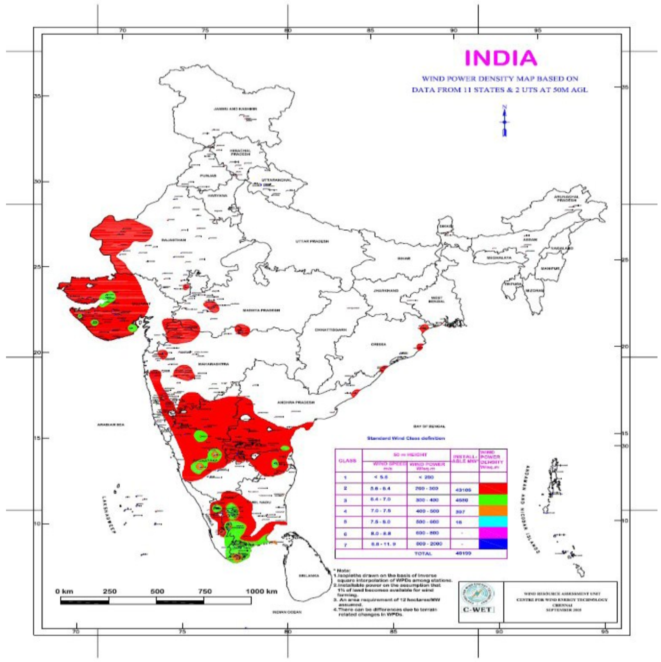


Figure 2 Wind power potential in India
(Source: Centre for Wind Energy Technology (C-WET) Govt. of India)

4. Conceptual Development of the HAWT

Figure 3 shows the experimental setup of windmill using PVC as blade materials. PVC blades are an excellent, quick, light, cheap and very easy. There has been some development in using large diameter PVC pipe as blade material. By cutting a PVC pipe lengthways and reshaping the leading and trailing edge with a file, and achieve a near perfect blade profile, and the process is simple.

Figure-3 Experimental Setup of HAWT Wind Mill

4.1 PVC Blade Design:

We measure the wind velocity at different places by anemometer and now finally we consider average velocity of wind is 8 m/sec. we get approx power 300 W from figure-5 at velocity 8 m/sec. Here we take TSR = 4 & considering 3 blades wind turbine. The radius of the turbine is 1.02m.

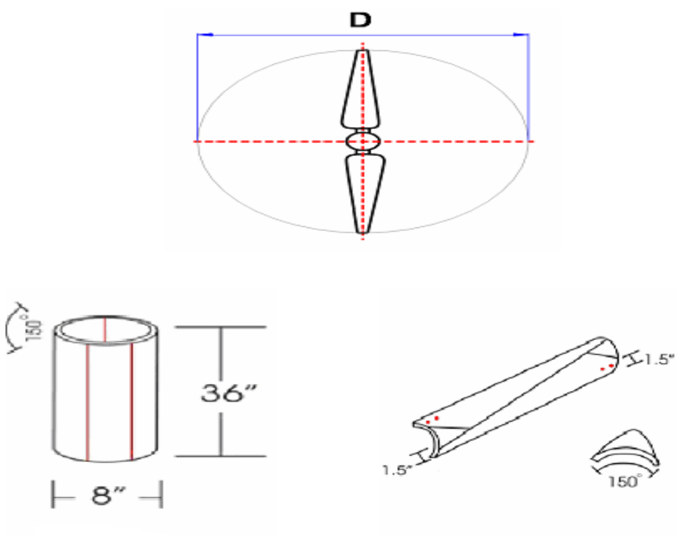


Figure-4 Design of PVC Blade

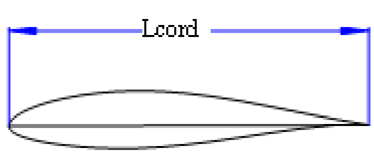
Speed of the turbine:

$$n = \frac{c \cdot TSR \cdot 60}{2 \cdot \pi \cdot R} = \frac{8 \cdot 4 \cdot 60}{2 \cdot \pi \cdot 1.02} = 299\ rpm$$

$$\omega = \frac{n \cdot 2 \cdot \pi}{60} = \frac{299 \cdot 2 \cdot \pi}{60} = 31.31\ {}^{rad}\!/_{s}$$

Chord Length:

$$L_{Chord} = \frac{4 \cdot D}{TSR^2 \cdot B} = \frac{4 \cdot 2.04}{4^2 \cdot 3} = 0.17m$$



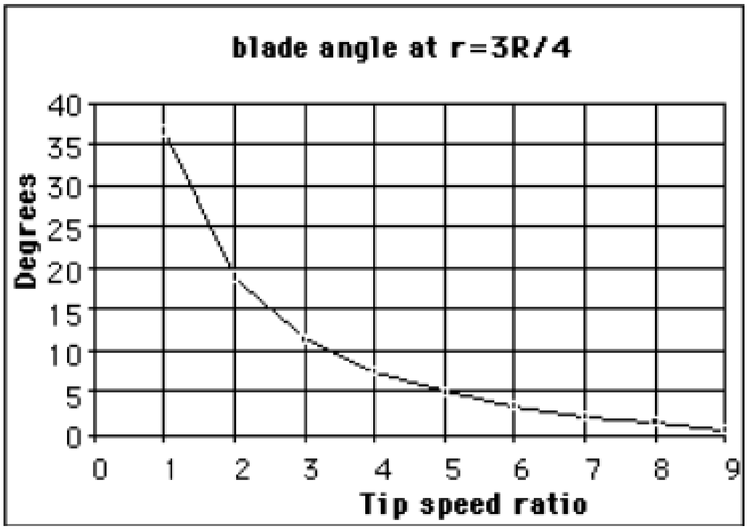
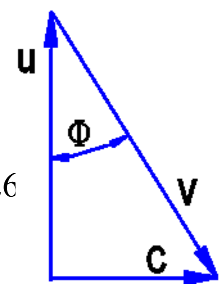


Figure-5 Blade angle Vs Tip speed ratio graph



From this graph we get blade angle (Θ) is 8°.

Ø = 8°+8° =16°

V = CsinØ = 8sin16° = 2.20m/sec

Lift force,

$$F_L = C_L \cdot \frac{1}{2} \cdot \rho \cdot V^2 \cdot A = 0.8 \cdot \frac{1}{2} \cdot 1.17 \cdot 2.20^2 \cdot 3.26$$

Drag force

$$F_D = C_D \cdot \frac{1}{2} \cdot \rho \cdot V^2 \cdot A = 0.01 \cdot \frac{1}{2} \cdot 1.17 \cdot 2.20^2 \cdot 3.26 = 0.0925N$$

4.2 Quarter the PVC pipe.

First of all we quarter the pipe (refer figure 6) then drawing straight line and measuring on round surfaces. Large sheet of paper is wrapped tightly around the pipe to get a straight line round the pipe. Then line one edge of the paper with this line to get straight lines going down the pipe. With the paper wrapped round the pipe we can mark the circumference. Then paper can fold in half and mark half way round the pipe. Then in half again and get quarters of the pipes. With these methods we should be able to draw good straight lines all over the pipe, dividing it lengthways into quarters. Now run saw down the pipe to cut it in half. Like so & then again into quarters refer figure-5. Now for each four quarters two things are required (1) Cut out a rectangle from the base so we can easily attach it to whatever we want to. Before you do the cut, drill a hole in the corner to improve the structural integrity of the material. Once the hole is drilled cut the rectangles out being careful not to cut past the hole. (2) Cut from the high tip of the base to the point.

Figure-6 Quarter PVC pipe

4.3 Field Tests:

The prototype of the PVC type HAWT was installed at the top floor of institute building and is shown in Figure 4. A preliminary test has been carried out on the device, which has operated successfully. In particular, the device has a very strong torque characteristic at low tip speed ratio, which means it is self-starting and may lend itself to applications such as water pumping. In addition, the rotor generates very little aerodynamic noise due to the low blade tip speeds. The average velocity of wind during various time periods is given table 3.

Table: 3 Time Period Vs Wind Velocity

Time Period	Wind Velocity
12-1 PM	5.72 m/s
1-2 PM	7.166 m/s
2-3 PM	3.108 m/s
5-6 PM	4.166 m/s
6-7 PM	3.58 m/s
7-8 PM	4.0833 m/s

In this experimental work, the practical performance of the PVC turbine blade profile of power mill has been measured in terms of battery voltage with respect to rotor speed as shown in figure 7.

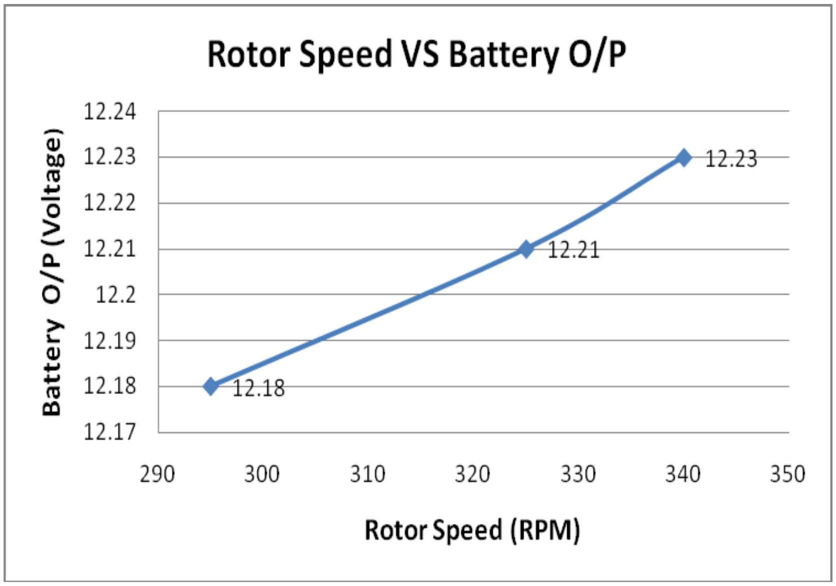


Figure-7 Rotor Speed VS Battery O/P

5. Conclusion:

On the earth, the search of safe clean and renewable energy is lesser, so we should use maximum renewable energy of the earth as wind. The mechanical and electrical energy is produced by wind energy using wind turbine at high altitude and seashore and open spaces. The present work demonstrates that PVC blade profile gives better power capacity with respect to increase in rotational speed of rotor. Further testing is required to confirm these initial tests. The project has proven to provide very successful training in wind energy for engineering undergraduate students.

Nomenclature:

C- Wind velocity (m/s)
ϴ- Angle of blade (degree)
C_D- Drag coefficient
V- Relative velocity
ρ- Density of air (kg/m^3)
R- Radius of the turbine (m)
TSR-Tip Speed Ratio
WEG- Wind Energy Generator

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