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# Design and Development of Darrieus Vertical Axis Wind Turbine for Rural Applications

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***Abstract—****This project (Design and Development of Darrieus Vertical Axis Wind Turbine) is about designing and manufacturing a Vertical Axis Wind Turbines VAWT to transfer the wind speed to a rotational motion using these turbines.*

*The main objective of this project is to design and build a self-starting vertical axis wind turbine for rural applications mainly for rotating the potter's wheel. A potter's wheel is a machine used in the shaping of round ceramic ware. The wheel may also be used during the process of trimming the excess body from dried ware and for applying incised decoration or rings of color. Use of the potter's wheel became widespread throughout the Old World but was unknown in the Pre-Columbian New World, where pottery was handmade by methods that included coiling and beating. Among various standard aerofoil blades we have used standard aerofoil blade S834 selected from NREL.*

*The main advantage of a vertical-axis wind turbine over a horizontal-axis wind turbine is its insensitivity to wind direction and turbulence. No yaw mechanism is needed. A VAWT can be located nearer the ground, making it easier to maintain the moving parts. VAWTs have lower wind startup speeds than the typical the HAWTs. VAWTs may be built at locations where taller structures are prohibited. VAWTs situated close to the ground can take advantage of locations where rooftops, mesas, hilltops, ridgelines, and passes funnel the wind and increase wind velocity.*

***Keywords:****— Wind turbine, vertical axis wind turbine (VAWT), Darrieus Wind Turbine, rural development, potter wheel, renewable energy*

## 1. INTRODUCTION

In recent days, it has been seen that the use of non-renewable sources of energy has caused much environmental damage than other human activity. Generation of electricity from fossil fuels like as coal and crude oil has led to very high concentrations of dangerous gases in the atmosphere. This has led to various problems being faced these days like ozone depletion and global warming. Vehicular pollution also been a major problem in recent years.

Therefore, alternative sources of energy have become very important and relevant to today's world. These sources, like the sun and wind, can never be exhausted and therefore are called renewable. They cause less emission and are available locally. Their use can, to a large extent, reduce chemical, radioactive, and thermal pollution. They stand out as a viable source of clean and limitless energy. This is also known as the non-conventional sources of energy. Most of the renewable sources of energy are fairly non-polluting and considered clean though biomass, a renewable source, is a major polluter indoors.

Wind power is the conversion of wind energy into a useful form of energy, like using wind turbine to make electricity, windmill for mechanical power, wind pump for water pumping or for the drainage, or for the sail to propel ships. The total amount of economically extractable power available from the wind is considerably more than present human power use from all sources. At the end of year 2009, worldwide capacity of wind-powered generators was 197 GW (gigawatt). Wind power now has the capacity to generate 430 TWh annually, which is about 2.5 percent of worldwide electricity usage. In last five years the average annual growth in new installations has been 27.6 percent. Wind power market penetration is expected to reach 3.35 percent by 2013 and 8 percent by 2018. Several countries have already achieved relatively high levels of wind power penetration, like 21 percent of stationary electricity production in Denmark, 18 percent in Portugal, 16 percent in Spain, 14 percent in Ireland and 9 percent in German in 2010. As per year 2011, Eighty three countries around the world are using wind power on a commercial basis.

A huge wind far might consist of several 100s individual wind turbine which are connected to the electric power transmission network. Off shore wind energy can harness the good wind speeds that are available offshore compared to on land, so offshore wind power's contribution in terms of electricity supplied is higher. Small onshore wind facilities are used to provide electricity to isolated locations and utility companies increasingly buy back surplus electricity produced by small domestic wind turbines. Although a variable source of power, the intermittency of wind seldom creates problems when using wind power to supply up to 20 percent of total electricity demand, but as the proportion rises, increased costs, a need to use storage like pumped-storage hydroelectricity, upgrade the grid, or a lowered ability to supplant conventional production may occur. Power management techniques like excess capacity, storage, dispatchable backing supply (usually natural gas), exporting and importing power to neighboring areas or reducing demand when wind production is low, can mitigate these problems.

Wind power, as an alternative to fossil fuel, is plentiful, renewable, widely distributed, clean, produces no greenhouse gas emissions during operation, and uses little land. In operation, the overall cost per unit of energy produced is similar to the cost for new coal and natural gas installations. The construction of wind farms is not universally welcomed, but any effects on the environment from wind power are generally much less problematic than those of any other power source.

The main advantage of a vertical-axis wind turbine over a horizontal-axis wind turbine is its insensitivity to wind direction and turbulence. A vertical-axis wind turbine can therefore be mounted closer to the ground, making it safer and cheaper to build and maintain. Tis still required access to plenty of wind though. The biggest drawback of a vertical-axis wind turbine is the inefficiency of dragging each blade back through the wind on each half rotation. A well-located horizontal-axis wind turbine is continuously driven by the wind once aligned and can be up to twice as efficient as an ideally positioned vertical-axis wind turbine. Still, the simplicity and variety of vertical-axis wind turbines makes for interesting reading as outlined below.

*Figure 1: Bearing*

## 2. METHODOLOGY

### *Base*

I have designed and constructed steel base. The base is steel and stands approximately 3 feet high and weighs roughly 70 lbs, as shown in figure. On its own the base will not support the torque and moments produced from our wind turbine, so a base extension and a connecting bracket will be required.

### *Cost Considerations for base*

The price of a base for a wind turbine is generally around 20 per cent of the total price of the turbine. It is therefore quite important for the final cost of energy to build base as optimally as possible.

### *Aerodynamic Considerations*

Generally, it is an advantage to have a tall base in areas with high terrain roughness, since the wind speeds increases farther away from the ground, as we learned on the page about wind shear

Lattice towers and guyed pole towers have the advantage of giving less wind shade than a massive tower.

### *Structural Dynamic Considerations*

The rotor blades on turbines with relatively short base will be subject to very different wind speeds (and thus different bending) when a rotor blade is in its top and in its bottom position, which will increase the fatigue loads on the turbine.

*Figure 2: Doing Paint on Stand*

### *Shaft*

To minimize weight, the 69 ½", 1 ½"diameter section of the shaft will be milled down to 1 3/8" to make the shaft uniform and to reduce weight. The central shaft is made up of Mild Steel. It should be able to bear the load as well as it should be corrosion resistant.

*Figure 3: Filling in holes for enlarging it*

### *Bearings*

Minimizing required start-up torque is essential for the wind turbine to self-start and thus, the success of my project. Without proper bearings my wind turbine will either not operate properly, or ruin the bearings that were used improperly, which could result in unsafe operating conditions. The bearings that I am using is shown in below figure, are inferior units that are not salvageable. Bearings can be very expensive, and for my particular setup I will require 2 roller bearings that are going to primarily centralize the shaft, and a turntable bearing to take the majority of the weight.

### *Center Mounts*

In order to connect the radial arms and the turbine blades to the center shaft, there needs to be a strong connection that will withstand the centrifugal and inertial forces caused by the rotation of the wind turbine. The center shaft mount, machined from aluminum, will slide over the end of the shaft and will be fastened with setscrews, enabling quick assembly and disassembly. The three radial arms will be bolted into the center mount via female clamps at 120 degree angles of separation. This will be a one-piece unit, designed using finite element analysis, to minimize weight and to reduce the possibility of failure.

*Figure 4: Central Mounts*

***Radial Connecting Arms***

The radial connecting arms are made up of steel and is connected with central shaft by using center mounts. There are 2 radial connecting arms used in my project.

***Blade design***

The ratio between the speed of the blade tips and the speed of the wind is called tip speed ratio. High efficiency 6-blade-turbines have tip speed/wind speed ratios of 6 to 7. Modern wind turbines are designed to spin at varying speeds. Use of aluminum and composite material in their blades has contributed to low rotational inertia, which means that newer wind turbines can accelerate quickly if the winds pick up, keeping the tip speed ratio more nearly constant. Operating closer to their optimal tip speed ratio during energetic gusts of wind allows wind turbines to improve energy capture from sudden gusts that are typical in urban settings. In contrast, older style wind turbines were designed with heavier steel blades, which have higher inertia, and rotated at speeds governed by the AC frequency of the power lines. The high inertia buffered the changes in rotation speed and thus made power output more stable.

*Figure 5: Basic Blade Shape*

The speed and torque at which a wind turbine rotates must be controlled for several reasons:

- To optimize the aerodynamic efficiency of the rotor in light winds.
- To keep the generator within its speed and torque limits.
- To keep the rotor and hub within their centrifugal force limits. The centrifugal force from the spinning rotors increases as the square of the rotation speed, which makes this structure sensitive to over speed.
- To keep the rotor and tower within their strength limits. Because the power of the wind increases as the cube of the wind speed, turbines have to be built to survive much higher wind loads ( like gusts of wind) than those from which they can practically generate power. Since the blades generate more torsion and vertical forces (putting far greater stress on the tower and nacelle due to the tendency of the rotor to process and nutat) when they are producing torque, most wind turbines have ways of reducing torque in high winds.

## 3. CONSTRUCTION AND ASSEMBLY

***Base and Stand***

Base is made up of concrete blocks and Stand is fitted above it. Stand is made up of Iron and painted with corrosion resistant paint. Slant height of stand is 7 feet 3 inch, Upper frame is a square of 2 × 2 ft. and lower frame is of 4× 4 ft. dimensions.

*Figure 6: Fitting Stand above Concrete Pillars*

### *Radial connecting arms and Center mounts*

Before fitting central shaft at stand, Center mounts is prepared and radial connecting arms are fitted in it. Radial connecting arms are fitted in center mounts by use of nut and bolts so that it can be removed while fitting central shaft in base stand. Radial arm is 1 m in length and having 1 inch outer diameter.



*Figure 7: Welding Central Mounts*

### *Bearings and Central Shaft*

Bearings fitted at center of stand one at upper frame and another at bottom frame. Before fitting central shaft we have to remove the radial connecting arms. Central shaft is fitted in this bearing having dimension 15 ft. length and 15 inch outer diameter.

*Figure 8: Fitting Central Shaft on Upper Bearing*

### *Blades*

First trace the aerofoil section on a drawing sheet with required dimensions. In my project the required dimensions are chord length of 2ft and depth of blade 4 ft. In the below figure of aerofoil the length is 2ft**.**Next step is to trace the aerofoil above the wooden block of thickness 1 cm and cut it. This wooden cutting is required for shaping the aluminum sheet in aerofoil shape. For each blade we require 6 wooden pieces and in my project I am using 6 blades so 36 wooden pieces required.

*Figure 9: Wooden Block Piece in Shape of Required Aerofoil*

Now connect these wooden pieces using mild steel rods as shown in below figure. Also connect the radial arm at centre of this mild steel rod.

Now wrap the aluminum sheet above the wooden blocks as shown in figure below. Drill the hole in aluminum sheet to pass the radial arm. Use small nails for fitting aluminum sheets above wooden block.

*Figure 10: Skeleton of Blade*

*Figure 11: Wrapping Aluminum over Skeleton of Blade*

Now fit the above created 6 blades in the central shaft using nut and bolts. Final Assembly of project is shown in below image

*Figure 12: Final Assembly of Wind Turbine*

***Transmission System***

For this pulley arrangement is used. One bigger pulley will be connected in central shaft of wind turbine and the smaller pulley will be connected in stand in which potter wheel is mounted. V belt drive is used for connecting these pulleys. Diameter of bigger pulley is 3.2 ft and diameter of smaller pulley is 0.8 ft. This arrangement will increase the rpm of central shaft 4 times.

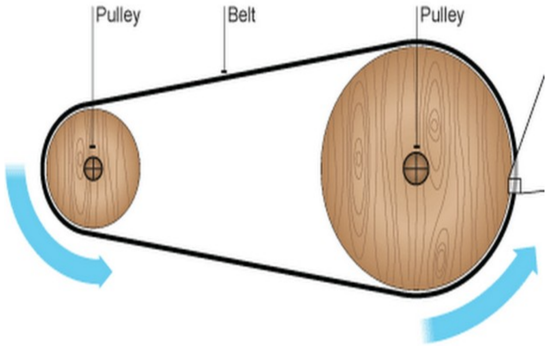


*Figure 13: Pulley arrangement*

*Figure 14: Bigger Pulley*

*Figure 15: Potter wheel will be connected in this stand*

## 4. RESULT AND DISCUSSION

This paper deals with the results obtained from the Experiment done on Darrieus Vertical Axis Wind Turbine. We have calculated the RPM of porter's wheel for one months.

I have performed the experiment from 10th Aug to 20th Sep for 30 days. Wind speed is optioned from weather website (https://www.worldweatheronline.com) and RPM of smaller pulley is calculated using Tachometer. The RPM of bigger pulley is calculated by formula D/d=n/N where D=diameter of bigger pulley

d-diameter of smaller pulley

N=RPM of bigger pulley

N=rpm of smaller pulley

After the Observations we concluded that

Maximum RPM measured on porter's wheel=240

Minimum RPM measured on porter's wheel=192

Below is the Graph between Porter's Wheel RMP measured wrt date

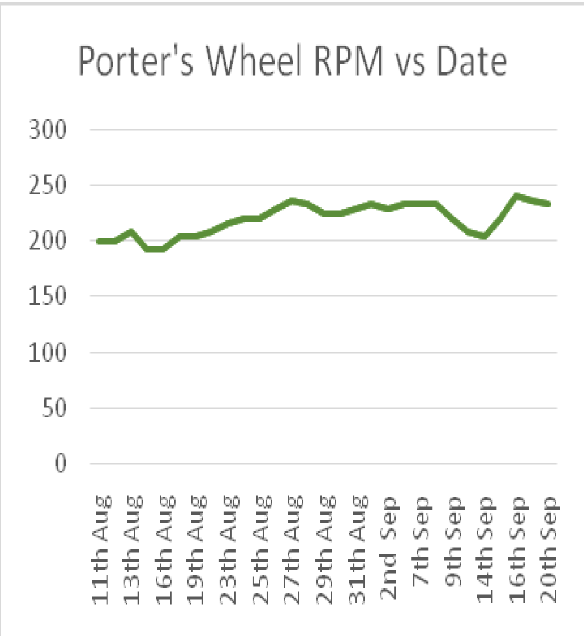


*Figure 16: Graph between Porter's Wheel RMP measured wrt date*

**Table 1: The Observations Records of Experiment**

| S. No | Date(2018) | Wind Speed in km/h | Speed of smaller pulley in RPM | Speed of Larger Pulley in RPM |
|---|---|---|---|---|
| 1 | 10th Aug | 16 | 196 | 49 |
| 2 | 11th Aug | 16 | 200 | 50 |
| 3 | 12th Aug | 16 | 200 | 50 |
| 4 | 13th Aug | 17 | 208 | 52 |
| 5 | 14th Aug | 15 | 192 | 48 |
| 6 | 16th Aug | 15 | 192 | 48 |
| 7 | 17th Aug | 17 | 204 | 51 |
| 8 | 19th Aug | 17 | 204 | 51 |
| 9 | 20th Aug | 17 | 208 | 52 |
| 10 | 23th Aug | 18 | 216 | 54 |
| 11 | 24th Aug | 18 | 220 | 55 |
| 12 | 25th Aug | 18 | 220 | 55 |
| 13 | 26th Aug | 20 | 228 | 57 |
| 14 | 27th Aug | 23 | 236 | 59 |
| 15 | 28th Aug | 22 | 232 | 58 |
| 16 | 29th Aug | 20 | 224 | 56 |
| 17 | 30th Aug | 19 | 224 | 56 |
| 18 | 31th Aug | 20 | 228 | 57 |
| 19 | 1st Sep | 21 | 232 | 58 |
| 20 | 2nd Sep | 21 | 228 | 57 |
| 21 | 3rd Sep | 22 | 232 | 58 |
| 22 | 7th Sep | 21 | 232 | 58 |
| 23 | 8th Sep | 21 | 232 | 58 |
| 24 | 9th Sep | 19 | 220 | 55 |
| 25 | 10th Sep | 17 | 208 | 52 |
| 26 | 14th Sep | 17 | 204 | 51 |
| 27 | 15th Sep | 19 | 220 | 55 |
| 28 | 16th Sep | 23 | 240 | 60 |
| 29 | 19th Sep | 23 | 236 | 59 |
| 30 | 20th Sep | 21 | 232 | 58 |

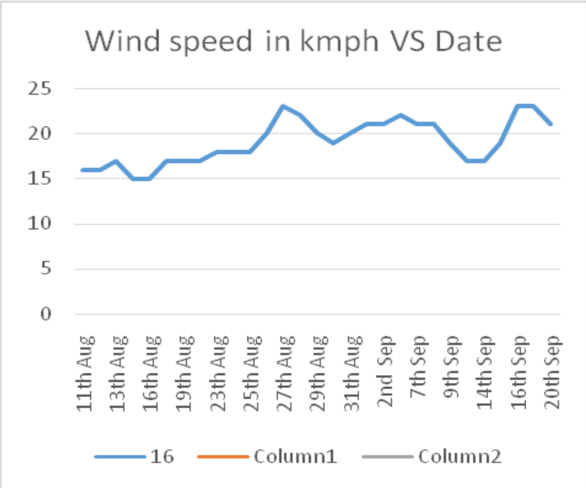


*Figure 17 : Graph between Wind speed in kmph(for Jabalpur) wrt date*

## 5. CONCLUSION AND RECOMMENDATIONS

This project (Design and Development of Darrieus Vertical Axis Wind Turbine) is about designing and manufacturing a Vertical Axis Wind Turbines VAWT to transfer the wind speed to a rotational motion using these turbines.

As per the observations, Porter wheel can easily work in Jabalpur conditions. This wind turbine can work anywhere in India with some modifications as per the conditions there. We have achieved a maximum speed of 240 rpm and Wind Turbine is worked well at this speed also.

The main advantage of a vertical-axis wind turbine over a horizontal-axis wind turbine is its insensitivity to wind direction and turbulence. No yaw mechanism is needed. A VAWT can be located nearer the ground, making it easier to maintain the moving parts. VAWTs have lower wind startup speeds than the typical the HAWTs. VAWTs may be built at locations where taller structures are prohibited.

***Some other advantages are given below:***

- No yaw mechanisms are needed. A VAWT can be located nearer the ground, making it easier to maintain the moving parts.
- VAWTs have lower wind startup speeds than the typical the HAWTs. VAWTs may be built at locations where taller structures are prohibited.
- VAWTs situated close to the ground can take advantage of locations where rooftops, mesas, hilltops, ridgelines, and passes funnel the wind and increase wind velocity.

**Table 2: Estimated cost of my Darrieus Vertical Axis Wind Turbine**

| **Parts** | **Cost** | **Quantity** |
|---|---|---|
| Ball Bearing | ₹ 1150 | 3 |
| Bigger Pulley | ₹ 550 | 1 |
| Bigger Stand | ₹ 4800 | 1 |
| Blade Arms | ₹ 1400 | 6 |
| Center Shaft | ₹ 750 | 1 |
| Clamp | ₹ 600 | 3 |
| Conical Blade | ₹ 5800 | 6 |
| External Sleeve | ₹ 320 | 4 |
| Foot Step Bearing | ₹ 900 | 1 |
| Labour Charges | ₹ 1500 | |
| Nuts, Bolts And Washers | ₹ 270 | 30 |
| Paint And Brush | ₹ 220 | 1 |
| Potter Wheel | ₹ 550 | 1 |
| Small Stand | ₹ 600 | 1 |
| Smaller Pulley | ₹ 320 | 1 |
| V-Belt | ₹ 500 | 1 |
| Wooden Shaft | ₹ 130 | 1 |
| **Over All Cost** | **₹ 23240.00** | |

So we can produce Darrieus Vertical Axis Wind Turbine at cost less than 30,000 and can reduce human efforts required for running Porter wheel.

## 6. SCOPE FOR THE FUTURE INVESTIGATION

- We can produce electricity by using generator which works between 100 to 200 rpm.
- We can also utilize this energy in wind pumps.
- We can also use Gearing mechanism in place of pulley system to generate higher RPM's, which further can be used for generating electricity.

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