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An innovative technique to make our highways more green using VAWT as a renewable energy source.

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Abstract—The work mainly focused on the utilization of maximum renewable sources for green highway missions and the design of portable vertical axis wind turbines to produce electrical energy in a very simple way. In this, the shaft of VAWT will rotate using the blades which will rotate by the wind draft or pressure thrust created by moving vehicles on the highway to produce electrical energy. The main focus is on to reduce the amount CO_2 which produce pollution by burning of fossil fuels to produce electricity by introducing clean potential energy source.Whenever the automobiles move from highways or expressways, there is a creation of pressure band on both the sides of the highways. This pressure band is created due to the imbalance of high-pressure and low-pressure energy band created by the movingvehicles. Due to this generated pressure band wind flow and create pressure thrust. The pressure thrust is sufficient to generate electricity through a designed vertical axis wind turbine.

Index Terms— Aerofoil, Electric power, Green Highway, Pressure trust, Vertical Axis Wind Turbine (VAWT), Watering, Wind Speed

1 Introduction

TODAY Wind energy is considered the fastest-growing clean energy source. In today's life, the demand for electricity is much higher than that of its production. Nowadays there are so many methods to produce electricity at our home also. The fluctuation in wind sources is a major issue. On highways, there is nearly constant wind velocity due to rapidly moving vehicles at high speeds up to 120 kmph. The motivation for this project is to contribute to the National Green Highways Project missionusing clean energy sources in a simple way to develop sustainable, Green, Clean, Safe, Pollution Free Highways.

A green highway is constructed as per a relatively new concept for roadway design that integratesecological sustainability and transportation functionality. An environmental approach is used throughout the planning, design, and construction. The result is a highway that will benefit transportation,public health, the ecosystem, urban growth, and surrounding communities.

As it is not suitable for all wind turbines to create electrical energy in all directions in minimum design cost, installation, and maintenance. To overcome all these problems VAWT is introduced which produces continuous energy in a useful manner. VAWT is adjustable, portable, low cost, and maintenance and it can produce energy in all directions of wind flow.

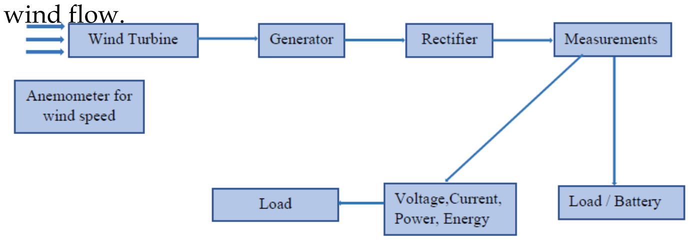
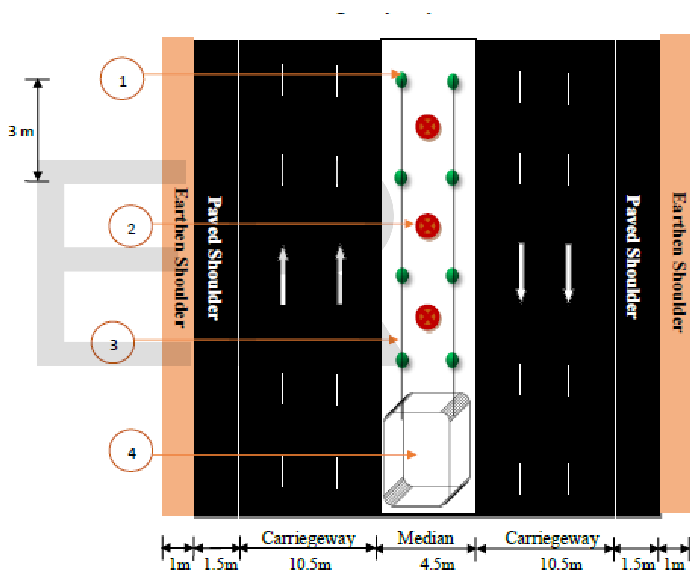


Fig. 1.Block Circuit Diagram



1 - Plant
2 - Dripline
3 - VAWT
4 - Water source

Fig.2. Highway layout

2 Working Principle

2.1 Median Plantation

The species to be planted in the median will be of low or medium height with ornamental value to enhance the visual experience of the road corridor. It will also act as a screen or glare preventor to prevent glare from the incoming vehicles. The species recommended for the median are mainly Bougainvillea and Kaner. Bougainvillea is considered the most suitable species as it has a great aesthetic value and it is found in various colors and shades. It can also withstand extreme temperature and climatic conditions and also has a low requirement of water. These species have been proposed by considering the requirement of water, the climatic conditions, and future management.

The technical specification for planting along the Highway is as follows-

2.2 Wind induced by moving vehicles in the direction of the wind turbine

All type of vehicles running on the road it may be all types of light or heavy vehicles, such as two, three, four-

TABLE 1
NO. OF PLANTS AND SPACING PER KM

Distance from embankment	1.0 mt. away from the toe of the embankment
Spacing between plant to plant	3 mts.
Spacing between rows	3 mts.
Size of the pits[Normal soil]	60x60x60 cms
For Alkaline soil [Usar]	By Augar
Water logged areas	mounds with height varying depending on the water level
No. of plants per km	333
Activity and time schedule	As per agreement
Height of the plant	1.5m to 2 m

wheelers, or even bigger vehicles. Optimum electrical energy may be generated if the wind is properly directed towards the wind turbine's blades. The study of the physical behavior of an object in airflow and the forces produced by air flows is studied under the branch of science called Aerodynamics. The blade performance of the turbine is decided by the shape of the aerodynamic profile. Even minor changes in the profile can greatly change the power curve.

2.3Vertical Axis Highway Wind Turbine

VAWTs are being populardue to interest in personal green energy solutions. VAWTs are targeting individual homes, farms, or small residential areas as a way of providing local and personal electrical energy. This reduces thedependency on other external energy resources and opens up a whole new market in alternative energy technologies.

As VAWTs are small, quiet, easy to install, can take the wind from any direction, and operate efficiently in turbulent wind conditions.

VAWTs have the following basic types: H-Rotor type, Darrieus type, and Savonius type. H-rotor type, derived from the traditional Darrieus type, which is equipped with straight blades rather than curved blades.Straight blades are easier to manufacture and install, results in low costs of material and manufacturing. H-Rotor type VAWT can drive by lift force andregulate itself well in various wind velocities. The H-rotor type of VAWT makes design and manufacturing much easier than HAWTs.

When the wind on the leeward side of the aerofoil travel a greater distance than that on the windward side a force is produced. The wind imposes lift and dragdriving forces on the blades of a VAWT.

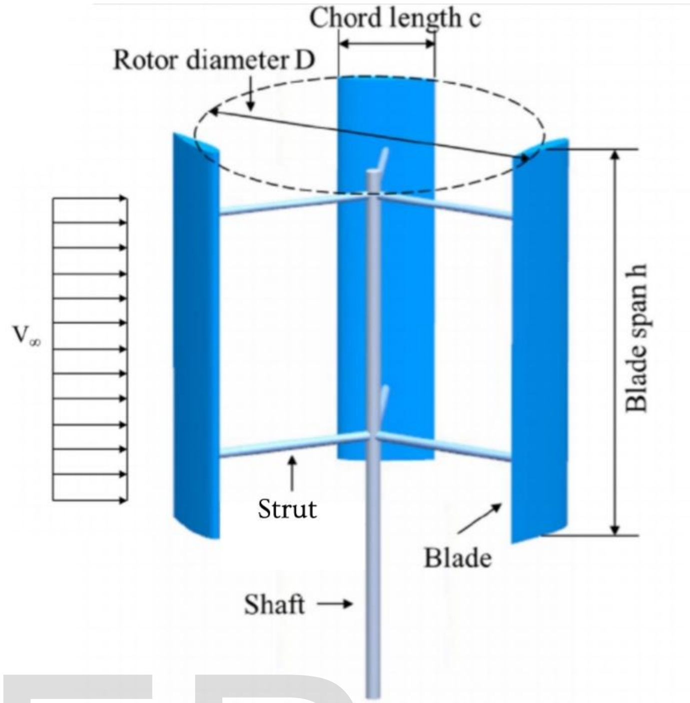


Fig.3.Schematic diagram of an H-rotor type VAWT: 3D view

The wind traveling on the windward side must travel at a greater velocity than the wind traveling along the leeward side. This difference in velocity creates a pressure differential.A low-pressure area is createdon the leeward side, pulling the aerofoil in that direction. This is known as Bernoulli's Principle.

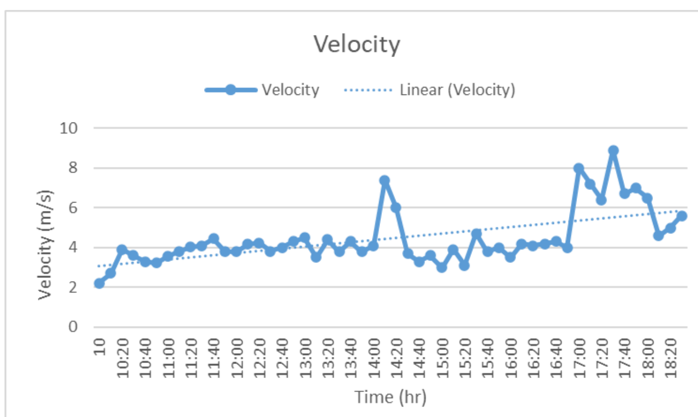


Fig.4.Velocity Vs Time Graph

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3 CONSTRUCTION

3.1 Blade

Wind turbine blades have an aerofoil shape cross-section. While designing the size of the blade, the weight and cost of blades must know. More number of blades give more torque but the slower speedand most alternators need fairly good speed to cut in. Two bladed designs are very fast and easy to build but can suffer from a chattering phenomenon while yawing due to imbalanced forces on the blades. Three bladed design is very common and a very good choice.More than 4 blades result in many complications, such as material strength problems with very thin blades. One-bladed designwith a counterweight is also possible.

The number of blades defines how much faster than the wind speed the tips of blades are designed to travel. Your blades will perform best at this speed but will work well over a range of speeds. The ideal tip speed ratio depends on rotor diameter, blade width, blade pitch, RPM needed by the alternator, and wind speed. High TSRs values are better for alternators and generators that require high rpm but the wind speed characteristics at your particular site will make a big difference also.

3.2 Center Shaft

The shaft of the turbine having length 1500mm and diameter 25mm is made up of lighter metal like cast iron was based on the availability of materials. The top and bottom end mild steel of length 1inch each are respectively are fixed to give strength to the hollow shaft. The yield strength of a mild steel shaft material (C50) from design data is 380Mpa. The safe load is 300N (Approx 30Kg).The shaft is subjected to bending and torsion stresses. The diameter of the shaft taken is 25 mm is safe after testing both bending and torsion.

3.3 Generator

For the generation of electricity from a vertical axis wind turbine, we chose a dynamo having capacity todrive a pump of half HP.

3.4 Bearing:

The bearing mechanism is used for smooth shaft operation. To have very less friction loss, the two ends of the shaft are pivoted into the same dimension bearing. The Bearing has a diameter of 25.4mm. Bearings are generally provided for supporting the shaft and smooth operation of the shaft.

3.5 Electrical Components:

The charge controller is used to prevent damage to the batteries.The charge controller will divert some power from the generator away from the battery and into a dump load.

Fig.5.Velocity measurement using Anemometer

5 DESIGN OPTIMIZATION

3.3 Turbine size as a function of power required

The power of the wind is proportional to air density, the area of the segment of wind being considered, and the natural wind speed. The relationships between the above variables are provided in equation 1

Pw=0.5ρAu3…………………………….….1

Pw=power of the wind *(W)*
ρ: air density *(kg/m3)* = 1.207 *kg/m3*
A: area of a segment of the wind being considered (*m²)*
u: undisturbed wind speed (*m/s*)

We have measured the highest wind velocity on Highway (Mumbai-Pune Expressway),
u=9m/s

Assuming,
Rotor diameter, D=0.8 m
Blade height, H=1.2 m
Number of blades for H-Type Darrieus type turbine, n=3

$$P_w = 0.5\rho Au^3$$

Pw=0.5∗1.207∗(1.2∗0.8)∗9^3
Pw=351.96 Watts

A turbine cannot extract 100% of the wind's energy because some of the wind's energy is used in pressure changes occurring across the turbine blades. This pressure change causes a decrease in velocity and therefore usable energy.

Betz'slaw indicates the maximum power that can be extracted from the wind, independent of the design of a wind turbine in open flow. The factor 16/27 (0.593) is known as Betz's coefficient. Practical utility-scale wind turbines achieve at peak 75–80% of the Betzlimit.

Actual Mechanical Power,

$$P_m = 0.5\rho Au^3 * \text{Betz}'s\ coefficient$$

$$P_m = 0.5 * 1.207 * 1.2 * 0.8Au^3 * \text{Betz}'s\ coefficient$$

Pm=0.5∗1.207∗1.2∗0.8∗4.53∗0.593

Pm=208.71**Watt**

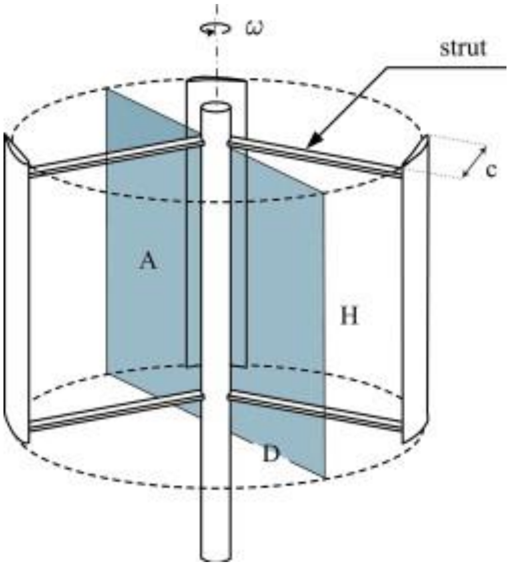

Fig.6.Nomenclature of VAWT

Tip Speed ratio,

$$\lambda = \frac{4\pi}{n} = 4.18$$

Rotor speed can be calculated by using TSR, which is given by,

As,
D_1= Rotor diameter =0.8 m
N_1= Rotor speed
u= wind velocity

$$\lambda = \frac{\pi D_1 N_1}{60u}$$

$$4.188 = \frac{\pi * 0.8 * N_1}{60 * 9}$$

N_1=900*rpm*

Considering gear ratio=0.5

$$Gear\ ratio = \frac{N_1}{N_2} = \frac{D_2}{D_1}$$

$$0.5 = \frac{900}{N_2}$$

N_2=180*rpm*

- **Design of the blade :**

Considering,

Solidity, **σ**=0.2

But

$$\boldsymbol{\sigma} = \frac{nc}{\pi D}$$

$$\mathbf{0.2} = \frac{3 * c}{\pi * 0.8}$$

c=0.167 m

where, c= chord length
D=Rotor Diameter

For the value of TSR=4.18
Power coefficient Cp=0.43

Thickness of the blade,

$$y = \frac{t * c}{0.2}[0.2969\sqrt{\frac{x}{c}} - 0.126\left(\frac{x}{c}\right) - 0.3516\left(\frac{x}{c}\right)^2 + 0.2834\left(\frac{x}{c}\right)^3 - 0.2834\left(\frac{x}{c}\right)^4]$$

At x=0.077; y=0.02349 m
At x=0.154; y=0.0070 m

But according to NACA,
For NACA0021,
Chord thickness = 20% to 30 % of Chord length
=0.3*0.167
=0.0501m

Area of blade,

$$As_1 = \int_0^c \left(\frac{y}{c}\right) - (-\frac{y}{c})dx = \int_0^c 2\left(\frac{y}{c}\right) dx$$

$$As_1 = \int_0^{0.167} 2\left(\frac{0.0501}{0.167}\right) dx$$

$$As_1 = 0.1002\ m^2$$

Assuming thickness of sheet material = 0.002 m

$$As_2 = \int_0^{0.167} 2\left(\frac{0.0501 - 0.002}{0.167}\right) dx$$

$$As_1 = 0.0962\ m^2$$

$$A = As_1 - As_2 = 0.1001 - 0.0962$$

A=$4 * 10^{-3} m^2$

Mass of each blade, $m = \rho V$
$= 2700 * 4 * 10^{-3} * 1$
=10.8 kg

Total weight of the blades, W=3*10.8*9.81
=317.844 N

- **Design of the shaft: -**

Shaft material-SS C50
$S_{ut} = 380 N/mm^2 \& S_{yt} = 250 N/mm^2$

Compressive stress,

$$\sigma_c = \frac{W}{A} = \frac{W}{\frac{\pi d^2}{4}} = \frac{317.844}{d^2}\ N/mm^2$$

Torque Produce, T=W*R
=317.844*0.4
=127.13 N.m

Shear stress,

$$\tau = \frac{16T}{\pi d^3} = \frac{16 * 127.3 * 1000}{\pi d^3} = \frac{648333.57}{d^3}\ N/mm^2$$

Using principle stress theory,

$$\sigma_c = \left(-\frac{\sigma_c}{2}\right) + \sqrt{(-\frac{\sigma_c}{2})^2 + \tau^2}$$

TABLE 2
DIMENSIONS OF VAWT

Sr.No.	Description	Dimensions
1	Blade	
i)	Length	1000 mm
ii)	Wing chord length	167 mm
iii)	Chord thickness	50.1 mm
2	Shaft	
i)	Length	1500 mm
ii)	Diameter	25 mm
3	Undisturbed Wind Speed	4.5 m/s
4	Density of Air	1.207 kg/m³
5	TSR	4.188
6	Solidity	0.27
7	Rotor Diameter	0.8 m
8	number of aerofoils/blades	3
9	Blade length/height	1 m
10	NACA aerofoil	NACA0021
11	The estimated coefficient of performance C_p	0.43

TSR =Tip Speed Ratio (it is the ratio of the peripheral speed of thetip of the blade to the wind speed), s = second, kg = kilogram, C_p=wind power coefficient/coefficient of performance/powercoefficient (it is a ratio of electricity produced by the windturbine to the total energy available in the wind),

$$\sigma_c = \left(\frac{-158.92}{d^2}\right) + \sqrt{(-\frac{158.92}{d^2})^2 + (\frac{648333.57}{d^3})^2}$$

$$\sigma_{all} = \frac{S_{ut}}{FOS}$$

$$\sigma_{all} = \frac{380}{3} = 126.67\ N/mm^2$$

$$\therefore \sigma_{all} = \sigma_c$$

∴d=17.216mm

$$\tau_{max} = \frac{0.5 S_{yt}}{FOS} = \sqrt{(-\frac{\sigma_c}{2})^2 + \tau^2}$$

$$\tau_{max} = \frac{0.5 * 250}{3} = \sqrt{(-\frac{158.92}{d^2})^2 + (\frac{648333.57}{d^3})^2}$$

∴d=25 mm
∴Diameter of shaft = 25 mm
∴Length of shaft = 1500 mm

Fig. 7.Mumbai-Pune Expressway Median

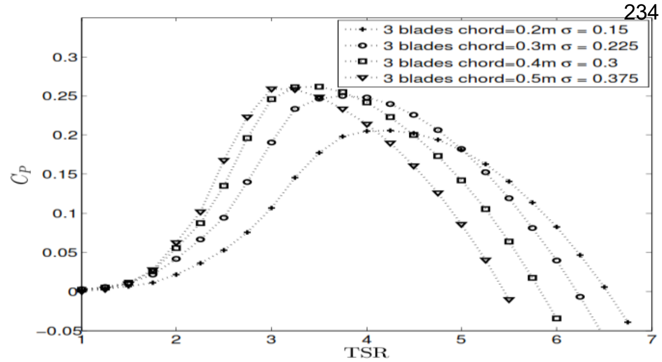

Fig. 8. Cp vs. TSR curve for an H-rotor

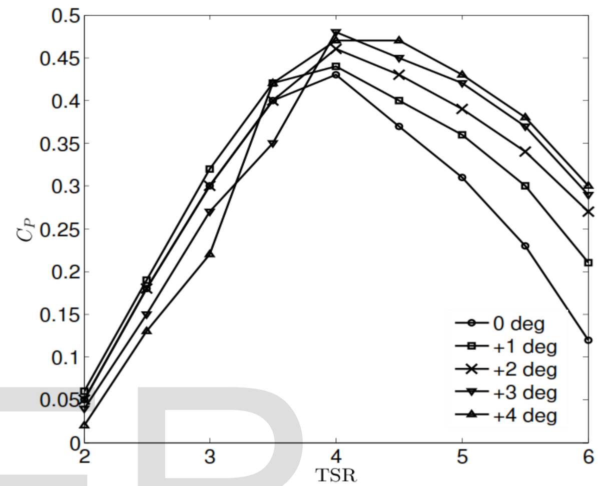

Fig. 9. CP vs. TSR for a NACA 0021 and chord 0.2

6 EXPECTED RESULTS

If 100 vehicles travel at theavg. speed of 70 km/hr with a regular average wind velocity of 4.5 m/s for 2hrs. An approximately 200 W/hr electric power will generate from designed vertical axis wind turbine (VAWT).

7 FUTURE SCOPE

In this project if we introduce solar panels for the electrical power generation, we will get extra energy or electric power on which we can drive motor-pump for watering purpose and use extra electrical energy for various applications like street lighting, Petrol Pumps or in future for the electric vehicle charging stations and for toll plaza, etc.

8 CONCLUSION

Conclusively, extensive data is collected on wind patterns produced by vehicles on both sides of the highway. Using the collected data, a vertical axis wind turbine is designed which is to be placed on the median of the highway. But only one turbine can not provide adequate power to drive the pump, multiple turbines in series on a long strip of the highway have potential to generate a large amount of electrical energy that can be used to drive pump for watering, power streetlights, other public needs like

charging station or even generate profits by selling the power to the grid. This design concept is meant to be sustainable and environment friendly.
The highway wind turbine can be used to provide electric power in any city around the globe where there are high vehicle density and high speed on road.

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