ISSN 2395-1621

Use of Vertical Axis Wind Mill for Making National Highways Green

#1Ms. Sonali Manik Bhuse, #2Mr. M. N. Kalgunde

1Student, Sinhgad Institute of Technology, Lonavala
2Assistant Professor, Sinhgad Institute of Technology, Lonavala

ABSTRACT

Wind energy is one of the fastest growing renewable energy sources. Based on the axis of rotation, wind energy can be classified into two types, Vertical Axis Wind Turbines and Horizontal Axis Wind Turbines. HAWT can be used for medium to large generation of power while VAWT can be used for small generation of power. In this paper the design fabrication prototype of H-Rotor Vertical axis wind turbine is made up of easily available raw material at minimum cost and placed on highway medians. This reduces the effects of climate change, global warming etc. The automobiles running on the highway creates a pressure difference on both the sides of highway. Thus, increasing kinetic energy which forces the turbine blades in clockwise direction. This drives the rotor connected to the generator. Generator convert kinetic energy into electrical energy. This produced energy can be used for multiple applications like toll gates, street lightning, charging stations of cars, watering purpose of the plant on the highway medians. This designed VAWT acts as a prevention of headlights of incoming vehicles on the highway, also reduces the pollution and risk of accident. In rainy season collect the water in water storage tank created on both the sides of highway. By using Generated electricity and collected water highway median plant can grow in summer and winter season. According to NACA 0021, blades can be fabricated. By using shear stress theory and principle stress theory, design of VAWT components and calculate the value of parameters.

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

ARTICLE INFO

Article History

Received: 8th August 2020

Received in revised form : 8th August 2020

Accepted: 13th August 2020

Published online : 13th August 2020

I. INTRODUCTION

The consumsion of fossil fuels has increased results in high CO2 emissions and large change in climate change. To solve these environmental problems, wind energy is considered as a fastest growing renewable energy source. In day today's life, demand of electricity is greater than its production. There ara so many methods to produce electricity at home but wind energy is reliable, affordable and more clean renewable energy source and reduces the pollution.

This projects mainly focused on generation of electricity on highway medians at minimum cost.

Wind turbines classification acceptance mainly on the axis of rotation. There are two types of wind turbines.

1. Horizontal Axis wind turbines
2. Vertical axis wind tturbine

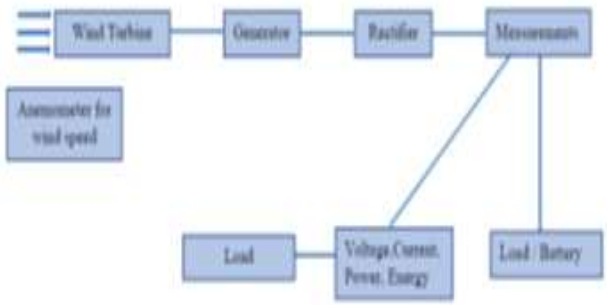

Fig. 1: Black Diagram of Wind Turbine

Working Principle of Wind Turbines:

Wind turbines works on aerodynamic principles.

Statement: Aerodynamic principle states that, the two primary forces at work in wind turbine rotor are lift force, which acts perpendicular to the direction of wind flow and drag force, which acts parallel to the direction of wind flow.

1. Horizontal axis wind turbines:

Horizontal axis wind turbines are used to generate the electricity for medium to large ratings and cost is also high. Maintenance and installation cost of this type of turbine is also high. It needed yaw mechanism and whole assembly is located on the top of tower. HAWT does not accept any direction of wind and design is complicated as compaired to VAWT. Most popular wind turbines are three bladed system, and three bladed system is more stable than two or one bladed system.

2. Vertical axis wind turbines

The main advantage of vertical axis wind turbines is, it can access the power in any direction, so it can install in city centres also. It can be available in small ratings. Whole assembly is located on the bottom of the tower and installation and maintenance cast is also less. It does not require yaw control mechanism. It is available in one, two or three bladed design, but for Stability, it is generally three bladed system. VAWTs are easy to install as compaired to HAWT.

How VAWTs produce electricity on highway?

A green highway is constructed as per relative new concept for roadway design that integrates ecological sustainability and transportation functionality. An environmental approach is used through out the planning, design and construction.

As per the new instructions the speed limit of national highway is increased up to 120km/hr on national highway we get the approximately constant velocity due to automobiles running on highway at high speed. Because of this it creates a pressure difference on both the sides of highway. Pressure accelerates on the turbine blades and it will start to rotate in clockwise direction. The rotor shaft is connected to the gearbox and it is used to convert low speed shaft to high speed shaft. This shaft is connected to generator and generator convert mechanical energy into electrical energy. But the single turbine can't produce the large amount of energy. To drive the pump or motor, a greater number of turbines are connected in series and generate the electricity. This generated electricity can be in many applications.

Effects of cutting of trees on highway sides?

In India almost 22km of road built in one day. There are some trees like neem, peele etc. on both the sides of roads in previous structure of roads. For expansion of roads these trees are cutting down, whose age is around 40-50 years. Because of cutting of these trees' effects like climate change, global warming as well as environment becomes polluted. And day today life of animals and human being becomes complicated. According to recent survey, on both the sides of roads almost 80 trees ate there. It means 80 trees/km*22kms=1760 trees are cutting down and almost 528000 trees are cutting in one year. While cutting these trees, we are not considering the emission of O2 and consumsion of CO2 amount. Because of cutting of these trees' environment becomes polluted and will not get fresh air.

For solution of this problem, we can plant the trees on highway medians.

How to plant and grow the highway median trees?

Select some specific highway, where the percentage of rainfall is greater. On both the sides of highway create underground water storage tank at some distance of easily available raw material like plastic, so it reduces the cost of tank. When rainfall start in rainy season, water is collected in water storage tank. In rainy season trees don't required water and in summer season the requirements of water are greater. By using drip irrigation system or sprinkler to take the water from water storage tank and generated electricity from H-Rotor VAWT, we can grow the highway median plants. For taking the water in water storage tank one pump is required. Government need not take the contract for watering plants on the medians of highway. Benefits of this project is environment becomes pollution free, also gets fresh air and highway become more cleaners and greener.

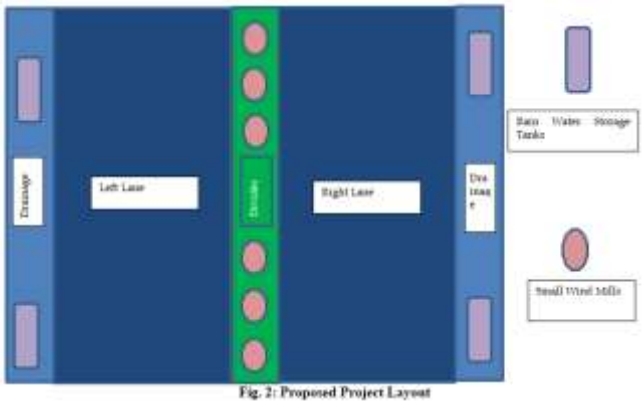

Fig. 2: Proposed Project Layout

II. PROBLEM STATEMENT

Currently road expansion is done according to ministry of act. By expanding roads, on both the sides of roads trees are cutting down whose age is almost 40-50 years. Because of cutting of these trees' environment will be polluted and effects occurs like climate change, global warming. In air increasing the percentage of CO2, and decreses the percentage of O2, and animals, human being life will become complicated, not get the fresh air.

III. OBJECTIVES

1. The main objective of this project is to generate the maximum amount of energy from the automobiles running on the highways in a minimum cost by designing VAWTs.
2. Reduce the effects like global warming and climate change, also reduces the air pollution.
3. Built a underground water storage tank both the sides of highway and collect the water in rainy season.
4. Generated electricity from VAWTs and water collected in water storage tank, we can grow the highway median plants easily.
5. VAWTs and plants on the medians of highway also acts as a prevention of incoming vehicles on opposite sides of highway, and it reduces risk of accident also.
6. Highway becomes more cleaner, greener and pollution free.

IV. METHODOLOGY

1. Fabricate the different parts of H-Rotor VAWT using easily available raw materials in a minimum cost.
2. Built a Tower using easily available material like wooden.
3. By using plastic blades are designed.
4. Make a shaft as pe requirement.
5. Connect all these components to get the prototype of VAWT.
6. This VAWT install in highway medians.
7. Built a underground water storage tank on both the sides of highways and collect water in rainy season.
8. Select irrigation system and pump to take the water from storage tank for watering purpose on highway median plants.
9. Generated electricity and collected water we can grow the highway median plants.

Design Components of Wind Turbines:

1. Blade- According to aerodynamic principle wind turbines blades have an aerofoil shape cross section.
While designing the blade chord length, height must be known. Blade acts as a barrier to the wind.

2. Shaft- when the rotor spins, shaft also spins and transfer the mechanical energy into rotational energy.

3. Generator- Generators concerts mechanical energy into electrical energy.

4. Bearing- Bearing mechanism is used for smooth shaft operation and are generally provided for supporting the shaft.

5. Yaw mechanism- To keep the wind turbine pointed into the wind, signals from a wind vane are monitored to check incoming wind direction.

6. Gearbox- In conventional wind turbines, the blades spin a shaft that is connected through a gearbox to the generator.

7. Hub- The blades are directly bolted to the hub.

8. Tower- To make a strong support, so it can withstand in high speed also.

Selection of Species:

The species to be planted in the highway medians should be low or medium height up to 5ft. These selected species can act as a screen or glare preventor to prevent glare from the incoming vehicles on the highways. The species recommend for the highway medians mainly Bougainville and Kaner. Bougainville is available in different colours. It can be also withstanding extreme temperature and climate conditions. Bougainville and Kaner has a low requirement of water.

Number of plants and spacing between these plants per km is shown in table below.

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

Table 1: Specification of Number of Plants and Spacing

Water Calculations:
How much quantity of water required per day for a selected species?
Water required per plant after one day = 2 litre.
From the period October to May, water requirement per plant = 1litre* 8months day (around 240 days)
= 240 litre water is required per plant
Selected specing in between two plants and two rows is 3 mtrs.
In a highway median we can plant two rows of plants.
Rows of plants in a 1km distance = 1000/3 = 333 plants in one row.
For two rows = 333*2 = 666 plant

Water requirement for 666 plants for the period of 8 months = 240 * 666 = 159840 litre
In summer and winter season 159840litre water required for highway median plants.

Calculation of Power:
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

$$Pw=0.5\rho Au3 \quad (1)$$

Where,
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 average 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

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

$P_w = 0.5*1.207*(1.2*0.8)*9^3$
$\mathbf{P_w}$ = 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's law 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 Betz limit.

Actual Mechanical Power,

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

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

Pm=0.5∗1.207∗1.2∗0.8∗4.53∗0.593

Pm = 208.71 **Watt**

`

Calculation of Tip Speed Ratio:

Tip Speed ratio,

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

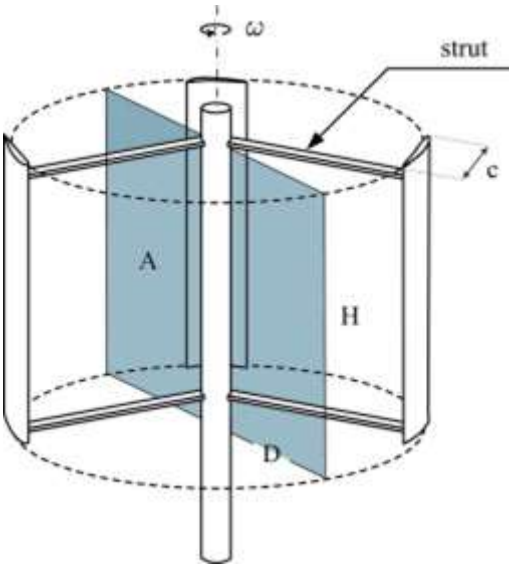

Fig. 3: Nomenclature of VAWT

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=1800 rpm

➢ **Design of the Blade:**

Considering,

Solidity, **σ** = 0.2

But

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

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

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,

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

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:

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

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

$$As_1 = 0.1002\ m^2$$

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,

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

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

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

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

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

∴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

V. RESULT

Sr.No	Description	Dimensions
1	**Blade** Length Wing chord length Chord thickness	 1000 mm 167 mm 50.1 mm
2	**Shaft** Length Diameter	 1500 mm 25 mm
3	Undisturbed Wind Speed	4.5 m/s
4	Density of Air	1.207 kg/m^3
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

Table 2: Calculated Parameters of VAWT

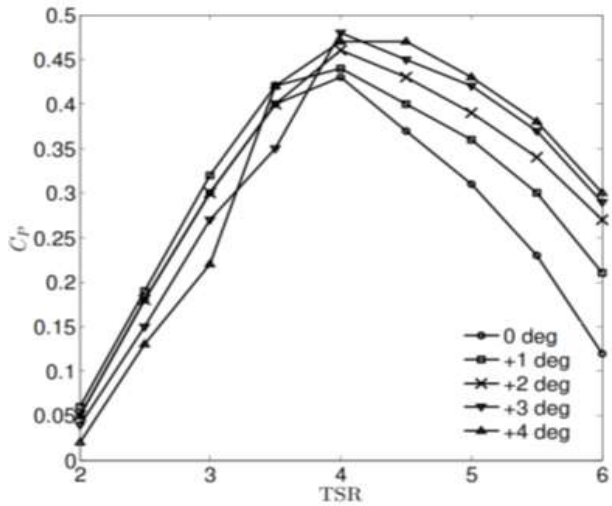

Fig. 4: TSR vs Wind Velocity

Measured highest average wind velocity is 9m/sec on national highway and theoretical calculated wind power from H-Rotor VAWTs is approximately 351.96 W and calculated mechanical power is approximately 208.71 W. In this project we get the idea of how much quantity of water is required for the period of October to May for the highway median plants. We get the value of blade length, chord length, blade area, solidity, TSR, COP, dimeter of shaft, length of shaft can be calculated theroticaly.

VI. FUTURE SCOPE

Fabricate the many number of VAWTs and connected in series in combination with solar panels on highway medians

to fulfill the all requirements. It generates large amount of energy using automobiles running on the highways. This generated electricity is mainly used for watering purpose of highway medians plants and use excessive amount of electricity to toll booth, street lightning, petrol pump, charging stations of cars etc.

VII. CONCLUSIONS

By calculating all these parameters, one can design and install H-Rotor VAWTs in the highway median. But only one turbine can not produce that much amount of energy to drive the pump or motor. So, connect many numbers of turbines in series and generate the electricity to drive the pump.

REFERENCES

[1] Niranjana S.J., "Power Generation by Vertical Axis Wind Turbine," International Journal of Emerging Research in Management &Technology ISSN: 2278-9359 (Volume-4, Issue 7).
[2] Mr. Mukesh Kumar Sharma, "Assessment of Wind Energy Potential from Highways," International Journal of Engineering Research & Technology (IJERT) Vol. 1 Issue 8, October - 2012 ISSN: 2278-0181
[3] Government of India, Minister of Road Transport & Highways Green Highway Policy-2015
[4] Suresh Mashyal, "Design and analysis of highway windmill electric generation," American Journal of Engineering Research (AJER) e-ISSN: 2320-0847 p-ISSN: 2320-0936 Volume-03, Issue-07, pp-28-32
[5] Rakesh Kumar, "A critical review of vertical axis wind turbines for urban applications," Renewable and Sustainable Energy Reviews 89 (2018) 281–291.
[6] Dr. K. V. Vidyanandan, "Advancement in Wind Energy Conversion System: An Overview", Member IEEE, 2015.
[7] F. Blaabjerg, Fellow IEEE and K. MA, Member IEEE, "Wind Energy System", Mar. 2017.
[8] W. Tian, B. Song, and Z. Mao, "Numerical investigation of wind turbines and turbine arrays on highways", Renewable Energy147(2020), pp. 384-398, Aug. 2019.
[9] D. Han, Y. Heo, N. Choi, S. Nam, K. Choi, and K. Kim, "Design, Fabrication, and Performance Test of a 100-W Helical-Blade Vertical-Axis Wind Turbine at Low Tip-Speed Ratio", Jun. 2018.
[10] Qing'an Li, "Effect of number of blades on aerodynamic forces on a straight-bladed Vertical Axis Wind Turbine," Energy xxx (2015) 1e12
[11] Vinit.V. Bidi, "Highway Power Generation using Low-Cost Vertical Axis Wind Turbine [VAWT]," International Journal of Engineering Science and Computing, Volume 7 Issue No.5, May 2017
[12] National Highways Authority of India, Circular no. 1013/1/2k/Env./638, dated on 21/06/2019
[13] Government Of India, Minister of Road Transport & Highways Green Highways E-books. http://morth.nic.in/green-highways
[14] MSRDC Website:- http://msrdc.org
[15] Handbook for national convection on "Proceedings of national convection on innovations in green highways" during 7th to 9th November 2016 at Madhyanchal Bhavan, Vasant Kunj, New Delhi
[16] Agreement between National Highways Authority of India (NHAI) & MP State Forest Development Corporation (MPSFDC) for plantation on NHAI lands, dated 9th August 2016.
[17] Induja Rai, NGHM, "Best Management Practices Manual of Green Highways"

Internet Link:

http://www.indiaenvironmentportal.org.in/content/415319/green-highways-plantation-maintenance-policy-2015/
https://nhai.gov.in/NGHMe/nationalgreenhighway.org/index.html
http://msrdc.org/Site/Common/ProjectListDetails.aspx?ID=81&MainId=31
http://www.mahasamruddhimahamarg.com/
https://en.wikipedia.org/wiki/Mumbai_Pune_Expressway
https://www.roadtraffic-technology.com/projects/mumbai/
https://nhai.gov.in/NGHMe/nationalgreenhighway.org/downloads/Green%20Highways%20Policy.pdf
https://nhai.gov.in/writereaddata/Portal/Images/pdf/guidelines-green-highway-project.pdf

