"POWER GENERATION BY HARVESTING WIND ENERGY DUE TO DISPLACEMENT ON HIGHWAY"

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***Abstract:* The objective of the task is to design a wind turbine to recapture wind energy from vehicles on the highway. Wind energy is considered the fastest growing clean energy source however; it is limited by variable natural wind. Highways can provide a considerable amount of wind to drive a turbine due to high vehicle traffic. This kinetic energy is unused. Research on wind patterns was used to determine the average velocity of the wind created by oncoming vehicles. The wind turbines are designed to be placed on the medians therefore fluid flow from both sides of the highway will be considered in the design. Using all of the collected data, existing streetlights on the medians can be fitted with these wind turbines. The design of the turbines consist of blades, collars, bearings, a shaft, gears and a generator. Additionally, since the wind source will fluctuate, a storage system for the power generated was designed to distribute and maintain a constant source of power. Ideally, the turbine can be used globally as an unlimited power source for streetlights and other public amenities.**

***IndexTerms* - wind turbine, power output, wind speeds, cp values, dynamic load**

I. INTRODUCTION

Energy is the Fuel for development: The global demand for energy is rising rapidly due to massive urbanization of huge developing countries like China and India. As we realize that fossil fuels are going to run out, we're trying harder to develop other means of generating the electricity on which we depend. Renewable resources, such as solar, hydro-electric, tidal powers are particularly attractive, although they do have drawbacks.

India has vast supply of renewable energy resources, even though energy crisis has become a great bottleneck in our sophisticated life. The total demand for electricity is expected to cross 2550,000 MW by 2030.The electrical sector have an installed capacity of 185.5 GW as of November 2011

The thermal power plant constitutes 65%, hydroelectricity has 25% and the rest is the combination of wind and solar power. In January 2012, over 700 million citizens had no access to electricity, and many people get electricity intermittently. Electrical consumption as per 2012 was 130 KWh in rural areas and 300 KWh in urban areas. India is currently suffering from major shortage for electricity. India should become one of the leading power producers in the world, but the current technologies are not sufficient to achieve our goal.

To overcome the above problem, we need to implement the new technologies in production of energy. Smart Wind power is the conversion of wind energy into useful form of energy such as electric energy by using wind turbines in the middle or either sides of the highways to generate electricity. Wind power is an alternate to fossil fuels which is plentiful, renewable widely distributed .clean energy produces no greenhouse gases during its operation and requires little land. So, we suggest that the energy can be harnessed in highways or roadways by placing the smart wind turbine in the middle of the highways. The smart wind turbine rotates more effectively because of the wind power generated in the roadways due to large number of vehicles passing at very high speed.

The smart wind turbine consists of the shaft which is mounted on the blades and the bottom end is connected to the generator. When the wind power increases certainly the number of rotations gets increased. So we can get large amount of electricity for domestic purposes. In this overall cost per unit of energy produced is less than the cost of new coal, natural gas and its installation. So the implementation can be made easier than any other methods

Wind energy is the fastest growing source of clean energy worldwide. This is partly due to the increase in price of fossil fuels and government incentives. The employment of wind energy is expected to increase dramatically over the next few years according to data from the Global Wind Energy Council. A major issue with the technology is fluctuation in the source of wind. There is a near constant source of wind power on the highways due to rapidly moving vehicles. The motivation for this project is to contribute to the global trend towards clean energy in a feasible way.

DIFFERENT POWER SOURCES

.In India the total installed Capacity of Generation (as on 28-02-2011) was 171926.40 MW. On May 2012, it increased to 202 GW. Various Power Sources i.e. Thermal, Hydro and Nuclear called as Conventional sources accounts for most of the contribution in Generation of Power. Contribution of various power sources to generation of Electricity is.

Table 1 Contribution OF different power sources

Power plant	Electricity generated
Thermal	64.75%
Hydroelectric	21.73%
Nuclear	2.78%
Renewable energy sources	10.73%

India's Energy demand, more than 50% is met mostly through Thermal power plant dependent on coal reserves. This fossil fuel is fast exhausting and also causing pollution Due to the rapid Industrialization and Advancing Technologies, the country's energy demand has grown an average of 3.6% per annum over the past 30 years. The total demand for electricity in India is expected to cross 950,000 MW by 2030.

Loss of power due to transmission and distribution is extremely high; varying between 30 to 45%.India's economic growths is adversely affected by power cuts resulting from shortage of electricity. India faced a power deficit of 73,050 million units between April 2007 and March 2008, according to an audit.

We have to seek alternative sources of Energy; Renewable Energy sources are the most promising fields in the search. The term Green energy can be associated with environment-friendly Generation, transport, storage and control of electrical energy .Solar power, wind power and the natural flow of water are resources that comply with our definition of Green Energy

II. PROBLEM FORMULATION AND IDENTIFICATION

Nowadays, the use of fossil fuel is growing exponentially. The sources of electricity such as coal, gas and oil has been reduced from year to year. So there is a need to find another source to produce stable electricity generation. Another effect of the lack of other sources is that the price of oil and gas is hiking. Because of these reasons, the use of renewable energy become essential and must be applied soon.

The electricity is one of the most needed energy because people need it in day to day life. There is need of generation of electricity because the resources that are used for electricity generation will be reduced year by year. In conventional way, the electricity is generated using coal, oil gas and etc. Since duel energy sources reduce every year, renewable energy is needed. The electricity generated by using these sources is more efficient and environmental friendly

GLOBAL APPLICATIONS

Before taking on this project, we wanted to know if there was a global interest in such technology and if other countries could benefit from the research. Our wind turbine design can be used in any city around the world. It is environmentally friendly. Labels in various languages and manuals will be provided for each specific city. Figure 1 shows a dramatic increase in the employment of wind energy globally. Wind power increased by nearly 20% in 2012 reaching a new peak of 282 GW. Various sources such as the Global Wind Energy Council show China as the leading country in the employment of Wind energy.

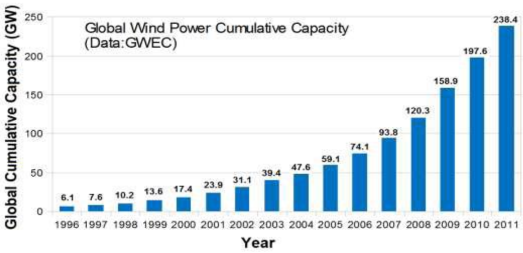


Fig 1 Global Trend In Wind Energy Generation Retrieved From The Gwec

Nationally, wind power is on the rise due to factors such as government incentives and increasing environmental awareness. Fig 1 shows the rise in wind energy production worldwide

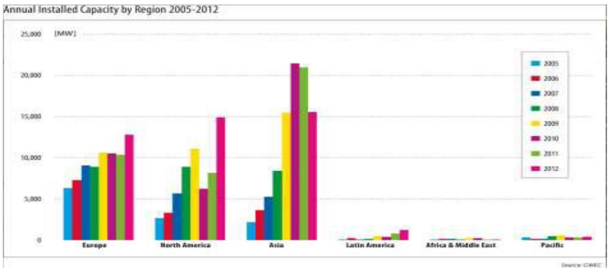
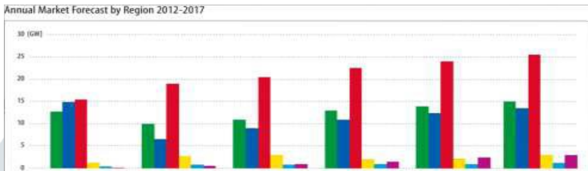


Fig 2 wind turbine installations by region.

Fig 2 shows the amount of wind turbines installed by region. According to the data, Asia is leading the world in terms of wind energy production followed by North America and Europe.



	2012	2013	2014	2015	2016	2017
Europe	12.7	10	11	13	14	15
North America	14.9	6.5	9	11	12.5	13.5
Asia	15.5	19	20.5	22.5	24	25.5
Latin America	1.2	2.8	3	2	2.2	3
Pacific	0.4	0.8	0.8	1	1	1.2
Middle East and Africa	0.1	0.5	1	1.5	2.5	3

Fig 3 market forecast for wind turbines by region

Fig 3 shows the market forecast for the employment of wind energy by Region. What should be noted is that the utilization of wind energy is expected to increase in all regions over the next few years.

III. LITERATURE SURVEY

From the design of the savonius turbine shows that a savories' turbine with 3 blades is produced 15 to 20 watt that energies in our prototype model at least 2 straight lights. For the highway, According to Joe Architecture if the dimension of the turbine is increase than produced 5 KW electricity and glow 1 to 3 straight light or signal light. In India or other country, if this project placed on the highway than the electricity problem on the highway reduced.

If we implement this method surely we can shift our country into a new dimension that is we need not depend upon any other country for electricity. Energy independence is the ability of a country or region to meet all its own energy needs. An energy dependent country is a country that has to import energy to meet its energy needs energy needs. Where as a country which has achieved energy independence can produce, transform and transport the energy that it consumes by itself.

Cost effective, green energy source for power generation can help to reduce power requirement. An efficient hybrid wind turbine is designed to be use in road side application for energy generation. This turbine is specially designed for road side applications which generate energy by utilization of natural wind and wind turbulence. A microcontroller operated effective charge controller has been developed. Charge controller charge battery from generated voltage and utilize this energy for later use. The presented system is cost effective, ready to use and user friendly system which used to serve specifically in highway lightning system. It is very useful in the areas which have heavy traffic on road without congestion. With the help of public aids, this system can be used to facilitate many houses and home and will be very handy for implementation.

This vertical axis highway windmill gives an idea about the new way of power generation and also about the new windmill technology. The power generation using VAHW is an ecofriendly method and power produced here is almost an continuous one By using this technology all the highways can be lightened without use of non- renewable energy resources. And if this method is implemented in all national highways we can able to produce large amount of power. And it can also provide job for many educated fellowship.

IV. WIND TURBINE SELECTION

most people may be familiar with the horizontal axis wind turbines that dominate wind farms. these turbines have much of the major components at the top of the tower. the blades must be configured in the direction of the wind. they also have gearboxes which amplify the angular velocity of the rotating blades. the blades must be very rigid and offset a certain distance to avoid collision with the tower. three-blade designs are generally used for commercial production of power with the assistance of computers to orient the blades into the wind.

Another major turbine configuration is the vertical axis wind turbine. There are several advantages and disadvantages to using a vertical wind turbine design. A vertical wind turbine design is selected because rotation generally commences at lower speeds. Vertical turbines are capable of capturing wind in any direction, whereas, horizontal turbines need to be pointed in the direction of the wind. The VAWT's can be operated at lower elevations. Additionally, heavy parts such as the generator and battery can easily be placed at the base of the turbine. This also makes it easier to maintain. Also, VAWTs generally have a lower noise level than

HAWTs. Disadvantages include higher torque produced on the central column, lower general efficiency dynamic loading on the blades.The two main types of VAWT's are the Darrieus and Savonius models.

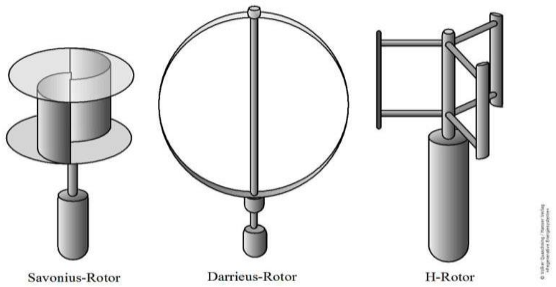


Fig 4 major types of wind turbines

The dominant force of a Darrieus turbine is the lift force. In a Darrieus configuration, airfoil cross-sectioned blades are rotated around a central column or shaft. Georges Jean Marie Darrieus patented this design in 1931. The Darrieus model can spin many times the speed of wind. The blades have a lower solidity and are more efficient than turbines relying on the drag force however, they are not self-starting.

Savonius models have high solidity but lower efficiency. This type of VAWT was invented by Sigurd Johannes Savonius in 1922. The dominant force behind the Savonius model is the drag force. Savonius turbines have 2 or three "scoops" in an "S"configuration. The curvature of the scoops reduces the drag when moving against the wind and with the wind. Savonius configurations are often employed when cost and reliability more important than efficiency. To make the most efficient highway wind turbine, we will be using a combination of the Darrieus and Savonius models. The Darrieus will provide better efficiency and the Savonius will aid in starting up.

MAJOR COMPONENTS

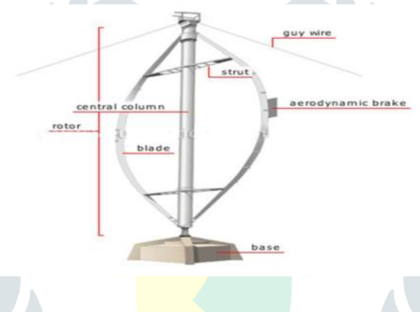


Fig 5 major components of a vawt

Fig 5 shows the major components of a vertical wind turbine. The most significant components are the blades, shaft and generator. The blades directly interact with the wind to transfer the kinetic energy of the moving fluid into rotational energy of the rotor. The rotor is connected to the shaft which may be connected to a gearbox or generator.

Our group designed a vertical axis wind turbine to utilize the wind produced by moving vehicles to generate electricity. These turbines will be placed along roadways that have high volume of fast moving traffic. The electricity generated will then be the stored in batteries. Since the electricity produced will be direct current (DC) it must be converted to alternating current (AC) before it can be used for lighting the street lamps, sold to the grid or any of the man ways we use electricity today. This means that the DC current must be passed through an inverter first before it is used.

The blades were the most difficult part of the design because they had to be propelled by wind in any direction. The original design called for curved blades angled so that as much surface area is exposed to the wind draft from oncoming vehicles as possible. The blades necessarily had to be lightweight. Wind turbine blades are basically modeled as airfoils. The driving forces on the blades are the lift and drag forces created by the wind. There is a difference in velocity of wind traveling on the windward and leeward side of the blade causing a difference in pressure. The Bernoulli equation can be utilized to calculate lift and drag forces when the velocity of the fluid moving on the leeward and windward side of the airfoil is known.

The central column design was relatively simple. It is a hollow tube whereon the blades are attached. It had to be strong enough to withstand the torque produced by the rotating elements.

The generator converts the mechanical energy to electrical energy through electromagnetic induction. The generator primarily consists of copper coils and magnets.

PRELIMINARY SOLIDWORKS DESIGN

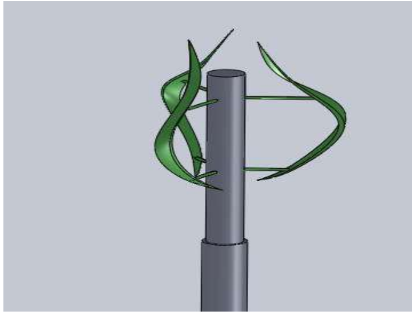


Fig 6 preliminary solidworks design.

Fig 6 shows the preliminary Solid works rendering by Geatjens Altenor. The idea was to curve and angle the blades to capture the maximum amount of wind.
To produce this product we hoped to find existing parts that fit within the design criteria and manufacture parts significant to the design. We also did a series of calculations in order to determine if the wind needed to rotate the turbines is sufficient enough to generate an adequate amount of electricity. Data was collected to determine the traffic patterns and energy storage requirements. Efficient placement is also important so that operators can harvest maximum energy from the wind draft created by automobiles.

V. ANALYTICAL ANALYSIS

POWER EXTRACTED FROM THE WIND

The maximum amount of power that can be extracted from the wind is directly proportional to the air density, area swept by the turbine blades, as and the wind velocity, v, cubed as shown in Eq. 1 (Hodge, 2009) this demonstrates that the most important variable in wind energy creation is the wind speed. Wind speed depends purely on the placement location and cannot be optimized therefore; the next major variable that can be optimized is the area. On the highway, wind speed can vary from 3 to as much as 8 mph roughly 5 meters from moving vehicles. For the purposes of demonstrative analysis, we will assume an average wind speed of 5 mph

$$Pw = \frac{1}{2}\rho Asv^3 \quad \ldots (1)$$

At standard temperature and pressure STP = 293K and 101.3 KPa, the density of air (ρ) is 1.204 kg/m3, Eq. 1 reduces to Eq.2.

$$Pw = 0.602Asv^3 \quad \ldots (2)$$

On the highway, wind speed can vary from 3 to as much as 8 mph roughly 5 meters from moving vehicles. For the purposes of demonstrative analysis, we will assume an average wind speed of 5 mph or 2.2352 meters per second.
The area in Eq. 1 and 2 is the swept area of the turbine which depends on the diameter and blade length of the turbine as shown in Eq. 3. The area swept by the turbine is limited by the width of the median. We wanted to use a minimum amount of space to allow for the safety of pedestrians and vehicles. We limited the diameter of the turbine to 3 feet and used a blade length of 2 feet.

$$A = D_t lb \quad \ldots (3)$$

The area swept by our wind turbine is 864 in2 or .557 m2.
Equation 1 is the power that can be harnessed by an ideal turbine. VAWT are at best about half as efficient therefore, the actual power generated is the wind power multiplied by a coefficient of performance Cp.

$$P_m = C_p P_w \quad \ldots (4)$$

The maximum value for the power coefficient is called the Betz limit. There are losses in wind turbine efficiency due to pressure changes, drag and other factors such as power losses in the electrical system. The theoretical limit to wind turbine efficiency is 59% as given by equation 5

$$Cp_{max} = \frac{\frac{8\rho AV^3}{27}}{\frac{1}{2\rho c^3}} = \frac{16}{27} = 0.592 \quad \ldots (5)$$

Wind System	Efficiency, % simple Construction	Optimum Design
Multibladed farm water pump	10	30
Sailwing water pump	10	25
Darrieus water pump	15	30
Savonius windcharger	10	20
Small prop-type windcharger (up to 2kW)	20	30
Medium prop-type windcharger (2 to 10 kW)	20	30
Large prop-type wind generator (over 10 kW)	----	30 to 45
Darrieus wind generator	15	35

Fig 7 cp values for various wind turbines

Fig 7 shows the typical coefficient of performance for various wind turbines.
Equation 6 is the final equation necessary to calculate the maximum power that can be extracted from the vertical wind turbine.

$$\text{Power extracted} = 0.602 C_p A_S v^3 \quad \ldots (6)$$

We used a very conservative coefficient of .30 for the hybrid Darrieus, Savonius turbine. The power we hope to extract is 1.12 joules or watt seconds. This shows the significance of gears and a power storage system.

Some analysis of fluid flow was also instrumental to the completion of the project. A Reynolds number is often employed to characterize fluid flow. In analysis of different possible turbine designs Eq. (7) defines Reynolds number.

$$Re = \frac{\rho V l}{\mu} = \frac{V l}{\nu} \quad \ldots (7)$$

In Eq.(7), V is velocity of fluid, l is a characteristic length, ρ is the density of fluid, μ is the dynamic viscosity of fluid and ν is the kinematic viscosity of the fluid. Traditionally, the characteristic length is the blade length. The calculated Reynolds number for our wind turbine is about 110000. A Reynolds number above 2000 signifies turbulent flow.

MAJOR COMPONANT

BLADES

The Darrieus turbine blades were selected first. These blades have a cross section in the shape of an airfoil such as that in Fig. 8

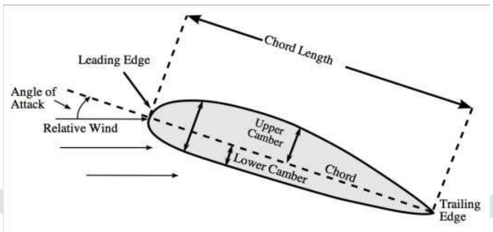


Fig 8 labelled parts of an airfoil

Major features of an airfoil are labeled in Fig.8. The leading edge is the point at the front of the airfoil with the maximum curvature. The trailing edge is the point at the extreme end of the airfoil. The chord line connects these two points. The angle of attack is the angle between the chord line and the relative direction of wind. The camber line (not pictured in Fig. 16) is median curve between the upper and lower camber. In describing an airfoil, it is important to note its maximum thickness in terms of a percentage of the chord line and the location of its maximum thickness relative to the chord line. Thickness is measured either perpendicular to the camber line or perpendicular to the chord line. The aerodynamic force created depends on the shape of the airfoil. The upper surface is related to high velocities and low static pressure and the lower surface has higher static pressure.

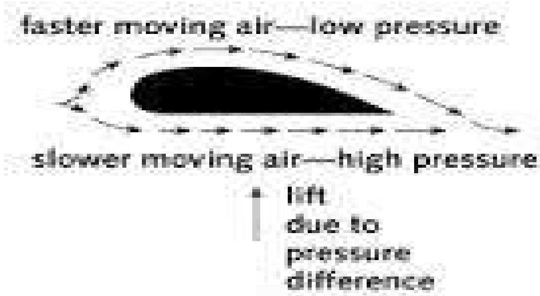


Fig 9 basic model of bernoulli principle

Fig 9 is a basic visualization of the Bernoulli Effect. The pressure difference can be calculated using Eq. (8), the Bernoulli equation. P1 and P2 is pressure, below and above the airfoil respectively, ρ is the density of the fluid, in this case air and V is the velocity of the fluid, g is gravity and h is the height from a specified axis. ρ

$$P_1 + \frac{1}{2}\rho v^2{}_1 + \rho g h_1 = P_2 + \frac{1}{2}\rho v^2{}_2 + \rho g h_2 \quad \ldots (8)$$

When an airfoil is placed in a wind stream, its shape forces the wind over the upper camber to move faster causing low pressure. A possible explanation for this is the principle of conservation of mass. An important assumption is that the air is incompressible. Basically, the air flows over the foil in stream lines but the curvature at the top of the airfoil forces the streamlines closer together. Since the fluid flow must stay the same, the velocity above the foil must increases. The wind below the airfoil is slower with higher pressure. This produces a lift force due to the pressure difference. Figure 18 demonstrates this phenomenon using the airfoil cross-section we designed in this project

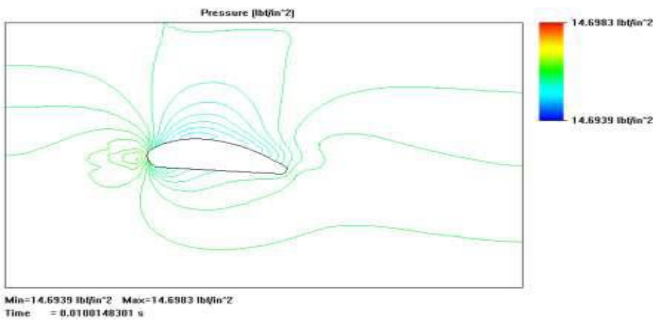


Fig 10 pressure isolines over our darieus blade

For obvious reasons, an airfoil shape that produces optimal lift is desired. An ideal symmetrical airfoil has a lift coefficient proven to be 2π times the angle of attack. Equation 9 is for a cambered airfoil. The lift coefficient must be adjusted by C_{L0} which is the lift coefficient when the angle of attack is zero.

$$C_L = C_{L0} + 2\pi\alpha \quad \dots (9)$$

By looking at the Eq. 2, it is clear that a larger angle of attack can increase lift but it is limited by the shape of an airfoil. Also, the associated drag coefficient would increase. Upon analysis of multiple airfoils, the lift coefficients were approximately close to the theoretical value therefore, the drag coefficients were investigated. A few low drag airfoils often used in the design of Darrieus wind turbines are NACA 0012, NACA 0018 and NACA 4415. Per the naming conventions for NACA airfoils, in symmetrical airfoil names, the first digit is maximum camber as a percentage of the chord. The second digit describes
The location of the maximum camber from the leading edge and the last 2 digits describe maximum thickness of the foil in relation to the coil. In airfoils with no camber, the first 2 digits are 0's. The ratings for each of the specifications including lift and drag coefficients for the selected airfoils are listed in Appendix A. Ultimately, we chose the NACA 4415 due to ease of manufacturing. It had a median thickness of the 3 and a larger camber.

After an airfoil shape was decided, we had to figure out how many blades would be most effective. Two or three blades are the standard but three blades were chosen because it resolves a few issues with vibrations, noise and starting.
Next we looked at the Tip Speed Ratio (TSR). Darrieus blades may spin several times faster than the wind. The tip speed ratio is the ratio of the tangential velocity of the blades to the wind velocity. The Tip Speed Ratio is one of the most important factors in the design of a wind turbine. Performance of a wind turbine is often modeled in a Cp versus Tip Speed Ratio curve such as that in fig. 20. If the blades are spinning too slowly, most of the wind will flow through the space between the blades however; if the blades are spinning too quickly it will be like wind flowing towards a solid wall. Having too many blades is not very effective and would require higher TSR's

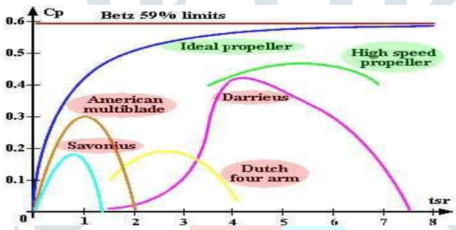


Fig 11 cp values for given wind turbines

Fig 11 shows the optimum Tip Speed Ratio for a given number of blades based on empirical data. The number of blades required has an inverse relationship to the optimum TSR. With a three blade configuration a tip speed ratio of about 4-5 is ideal.
The angular frequency of the Darrieus blades can be calculated using Eq. 10 wherein λ is the TSR and r is the radius of the turbine.

$$\omega_f = \frac{\lambda v}{r} \quad \dots (10)$$

With a wind velocity of 5 mph or 134.11 meters per min, a radius of 18 inches and a tip speed ratio of 4, the angular frequency of the Darrieus blades is 186.7 rpm.

4.2.2 STRUTS

Struts are used to attach the Darrieus blades to the collar. They had to be lightweight yet resistant to deformation. We decided to use 3/8 in aluminum rods and thread the ends. The maximum stress concentration would therefore be in the thread, therefore we used equations.

Equation 11 and Eq. 12 are used to calculate the body shear stresses due to the moment from torque at the exterior of the screw body and the axial normal stress respectively. The body shear stresses due to the torsional load for our struts are 16.7 Mpa and the axial normal stress is .097 Mpa.

$$r = \frac{16T}{\pi D r^3} \quad \dots (11)$$

$$\sigma = \frac{F}{A} = \frac{4}{F\pi D r^2} \quad \dots (12)$$

Empirical data suggest that the first thread amongst the engaged threads will carry a greater portion of the load. This is about .38F. The bearing stress with one thread carrying .38F can be calculated using Eq. (13).

$$-\sigma B = \frac{F}{\pi D m n t p/2} = \frac{2F}{\pi D m n t p} \quad \dots (13)$$

The thread root bending stress with one tooth carrying .38F is given by Eq. (14).

$$r = \frac{3V}{2A} = \frac{3F}{2\pi D m n t p/2} = \frac{3F}{\pi D m n t p} \quad \dots (14)$$

There is a transverse shear stress at the center of the thread due to the loading but the transverse stress at the top of the thread root due to bending is 0. The calculated normal and shear stresses are arranged in table 2.

Table 2 Dimensional stresses on the screw

σ_x	0.8597Mpa	r_{xy}	0.0
σ_y	-0.197Mpa	r_{yz}	16.5Mpa
σ_z	0.0	r_{zx}	0.0

To find the von Mises stresses, principle stresses must be calculated using Eq. (15).(16)

$$\sigma_1, \sigma_2 = \frac{\sigma_x+\sigma_y}{2} \pm \sqrt{(\sigma_x - \sigma_y \ /2)^2 + \tau_{xy}{}^2} \quad \text{... (15)}$$

$$\tau_{max} = \frac{\sigma_1-\sigma_2}{2} \quad \text{... (16)}$$

A safety factor was calculated using Eq. (17).

$$n = \frac{Sy}{6} \quad \text{... (17)}$$

COLLAR

Custom collar was designed to attach the three Darrieus blades to the shaft. Figure 4.6 shows the custom designed collars.

Fig 12 collar for darrieus blades

The collar fits snugly around the shaft with 3 threaded holes evenly spaced aroun its center. One end of each of the three rods will be threaded through the collar and shaft. The other end of the rods will be threaded and bolted to the blades.

SHAFT

The shaft is integrated into the system to transmit power from the prime mover, which in this case are the rotating blades to the generator. The shaft is made from ¾ inch stainless steel. Each Darrieus blade will be mounted to two 3/8 inch aluminum struts, which are in turn mounted to the collars. The three equally spaced threaded rods are threaded at both ends and meet in the center of the rod. The Savonius blades are also attached to the central column as well as the bearings and a gear. Two bearings are placed on either side of the gear for stable support and well balanced loading of the bearings.

The shaft will experience a combination of normal, torsional shear and bending stresses from the applied loads. The distortional energy theory of failure was utilized to analyze the shaft.

With a wind velocity of 5 mph the angular velocity of the turbine is 128 rpm from the average of the Darrieus and Savonius blades.

The total torque on the central column can be found using the known output power and angular velocity as in Eq. (18).

$$T = \frac{p}{\omega} \quad \text{... (18)}$$

BEARINGS

For bearing selection started with the dimensions that best suited to design. The dimension desired was a .75 inch diameter to fit the shaft. We found a bearing with these dimensions shown in Fig. 30.

Fig 13. Bearing

Next, we checked if the load rating on this bearing is enough to support our design load needs. The dynamic load rating is 193 lbs on McMaster-Carr; the static loading is much less.To find our loading needs we started with some known parameter shown in table 3

TABLE.3 KNOWN PARAMETERS FOR DYNAMIC LOAD CALCULATION

Fa	13.5	Axial load(lbf)	Xo	0.02	Assumed weibull parameter
Fr	4.3	Radial load(lbf)	Sigma	4.459	Assumed weibull parameter
V	1	Inner ring rotates	Af	1.2	Application factor
R	0.9	Reliability	A	3	Roller bearing parameter
N	150	Speed(rpm)	B	1.483	Roller bearing parameter
Co	6.2	Static load rating(lbf)	C10	12.7	Dynamic load rating(lbf)

Other parameter needed was the equivalent load (Fe) in Eq. (19)

$$Fe = XiVFa + YiFr \quad \text{... (19)}$$

Fa/Co	e	X1	Y1	X2	Y2
0.014	0.19	1	0	0.56	2.30
0.021	0.21	1	0	0.56	2.15
0.028	0.22	1	0	0.56	1.99

To solve this equation we needed the values for X and Y. the first step was to Calculate Fa/Co to get a value "e" and then compare e to Fa/VFr and using Fig. 4.9 we were able to get the values for X and Y. If Fa/Co is less than .014, the instructions are to use the values for .014

Fig 4.9. x and y values to determine fe

MOTOR

The gears, generator, battery and other components were bought and are housed at the base of the turbine. The main consideration for the motor is that it requires very low rpm's to produce a high voltage. The challenge was that the angular frequency is inversely proportional to the torque. The base is not shown in the Solid Works model however, it will be attached to the shaft using the bearings in fig 4.10 once the turbine is designed, a gearbox may be designed to step up the power output

Fig 14 generator selected

GEARS

Most turbines have gearboxes to "step-up" the angular velocity of the turbine. This is particularly important in the design of the highway wind turbine because it is placed at lower elevations with slower moving wind. With a wind speed varying between 0 and 8 miles per hour

To amplify the number of rotations, used a simple gear train consisting of 2 gears. Initially, we wanted to produce the maximum ratio of 10 with one set of gears however, it would run the risk of interference.

We chose gears to achieve a gear train value of 10 using Eq. (20).

$$e = \frac{\text{product of driving tooth number}}{\text{product of driven tooth number}} \quad \ldots (20)$$

The minimum amount of teeth on the pinion necessary to avoid interference is given by Eq. (21).

$$Np = \frac{2k}{(1+2m)\ \sin\theta} 2(m+\sqrt{m + (1+2m)\sin\theta\, 2}\,) \quad \ldots (21)$$

The pinion gear is made of high strength steel whereas the mating gear is made of cast iron.

Fig 15 pinion and mating gear.

For a pressure angle of 20 degrees, this set of gears would have been acceptable, however when the pressure angle was changed to 14.5 in a template created specifically for this analysis, the minimum number of teeth was 30. The pinion would receive the velocity from the shaft at about 130 rpm and using the train value from Eq. (13) the mating gear would rotate at 650 rpm.

OUTPUT EFFICIENCY

S.N	Velocity of wind	Efficiency
1	5 mps	32%
2	8 mps	65%
3	11 mps	92%

VI. CONCLUSION

Conclusively, extensive data is collected on wind patterns produced by vehicles on both sides of the highway. Using the collected data, a wind turbine is designed to be placed on the medians of the highway. Although one turbine may not provide adequate power generation, a collective of turbines on a long strip of highway has potential to generate a large amount of energy that can be used to power streetlights, other public amenities or even generate profits by selling the power back to the grid. This design concept is meant to be sustainable and environmentally friendly. Additionally, a wind turbine powered by artificial wind has a myriad of applications. Theoretically any moving vehicle can power the turbine such as an amusement park ride or freight train. The highway wind turbine can be used to provide power in any city around the globe where there is high vehicle traffic.

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