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Smart Vertical Axis Highway Wind Turbine

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ABSTRACT: *Energy is an important aspect of our everyday life. The resources we use are limited whereas the population consuming the same is increasing day by day. Nowadays the requirement for electricity is much higher than its generation; hence the main objective of our work is to produce electricity at low cost with no effect on the environment. The objective of the work is to design a wind turbine to recapture wind energy from vehicles on the highway. A considerable amount of wind energy is produced due to the pressure difference created by the moving vehicles on the highways. This wind energy can be utilized for the generation of electrical energy with the help of vertical axis wind turbines. This work aims to extract this energy in the most efficient manner. A vertical axis wind turbine can be installed on the median of the roads so that the wind from both sides of the median will act tangentially in opposite directions on both sides of the turbine thereby increasing the effective wind speed acting on the turbine. This wind flow will depend on the velocity of the vehicle, size of the vehicle, and intensity of the traffic. Based on the studies made an optimal wind turbine design has to be made. The wind power harnessed through this method can be used for street lighting, traffic signal lighting, toll gates, etc.*

KEYWORDS: VAWT, HAWT, H-rotor, semi-guy-wired tower, Noise emission, Sound power level, Highway Power, Windmill, Renewable Energy.

INTRODUCTION

In today's life electricity has become one of the basic needs like food, water, etc to people. Power is needed in every part of life from household to industrial level. A day without electricity is compared to a nightmare. Since its inception in the very first days of the 21th century, the demand for electricity is increasing with time. Electricity reduces human labor, saves time, and provides precise output. Though the demand for electricity is increasing, the production of electricity is not adequate. Currently, around 68% of electrical power produced from the thermal power plant. In a thermal power plant, power generation is based on fossil

fuels, diesel, which is very limited, less available, and concern is that these are going to be finished one day.
By using a shaft to transfer the torque, VAWTs can have the generator and other key parts located at ground level which enables designing them focusing on performance and economy rather than size and weight. Furthermore, maintenance and modifications are made easier with these parts placed on the easy accessible tower base. Yaw motors are superfluous since VAWTs are omni-directional which allows for a design with essentially only one moving part, which is made up of the rotor, shaft and generator rotor which are all jointed. Also, the concept has shown potential for lower noise emissions. Furthermore, in it has been shown that the concept is more suitable for up-scaling than the HAWT concept. However, torque ripple on the shaft and bending moments on the blades due to constantly changing angle of attack are issues that are only addressed for VAWTs, making dimensioning for fatigue more complex. With the increase in environmental issues, the demand and utilization of renewable energy resources has increased significantly. Alongside solar energy, recent developments and research have made wind energy as the mainstream method of power generation through renewable resources. Production of power by harnessing the energy from wind has huge prospects.

In today's life electricity has become one of the basic needs like food, water, etc to people. Power is needed in every part of life from household to industrial level. A day without electricity is compared to a nightmare. Since its inception in the very first days of the 21th century, the demand for electricity is increasing with time. Electricity reduces human labor, saves time, and provides precise output. Though the demand for electricity is increasing, the production of electricity is not adequate. Currently, around 68% of electrical power produced from the thermal power plant. In a thermal power plant, power generation is based on fossil fuels, diesel, which is very limited, less available, and concern is that these are going to be finished one day. Considering Europe, more investments have been made in wind energy than any other renewable energy technology. Wind turbines are installed at carefully planned and tested sites with good wind resource to convert the kinetic energy from wind into electrical power. However, the major challenge in this regard is to find and select a site that satisfies the required working conditions of a wind turbine.

After all, it is expected that this research work will make a little contribution to the global trend towards green energy and reduce the dependency on non-renewable sources.

History of vertical axis wind turbines

Actually, vertical axis windmills might have been in use in the Afghan highlands as early as the 7th century BC. These early VAWTs where simple devices based on aerodynamic drag, the wind was simply pushing the blades of the turbine and thus creating torque. Using aerodynamic lift created by pressure difference due to the shape of the blade is far more efficient than using drag and the first lift-based vertical axis wind turbines were invented by Darrieus in 1931. Darrieus patent cover both the troposkein “egg beater” shaped turbine with curved blades mounted directly to the rotating tower/shaft that is supported by guy wires at the top and the so called H-rotor with straight blades and struts connecting them to the shaft placed inside the tower.

During the 1970-80s there where large research programs in North America focusing on the Darrieus concept, for example Sandia National Laboratories tested different configurations and sizes of the Darrieus turbine. A company called The FloWind Corp utilized much of the Sandia technology to build commercial wind farms using turbines ranging up to 300 kW which initially proved to be quite reliable and efficient. In Quebec, a record-breaking 4.2 MW Darrieus turbine known as Éole C was built in the late 1980s. However, during this period the blades which were designed to flex, were usually made of aluminum which is not very endurable to cyclic stress, so with time problems with fatigue on the blades started to appear which ultimately lead to failures. These problems together with withdrawal of funding finally stalled the development. Today most of the VAWT projects regard small scale turbines like Ropatec from Italy, Turby from the Netherlands or the innovative Swedish offshore concept SeaTwirl which features a floating tower and kinetic energy storage using sea water. In recent years there has been a renewed interest in larger VAWTs, not least because of findings within the VAWT research project.

Wind Energy Scenario in Bangladesh

At a glance, references show that with a population of 146.2 million electrification rate is 59.60%. Total electrical energy installed capacity is 12229 MW (2016) [1] and total installed wind energy is 1.9 MW. Wind energy potential in Bangladesh is over 20,000 MW, the wind speed being < 7 m/sec. In Bangladesh, research in the field of wind energy began only a few years ago, which had shown that some southern districts of Bangladesh have a very good potential of wind energy. Bangladesh Centre for Advanced Studies (BCAS) in collaboration with Local Government and Engineering Department (LGED) and an international organization namely Energy Technology and Services Unit (ETSU) from UK with the funding from Department of Foreign and International Development (DFID) has attempted to monitor wind conditions at seven coastal sites for a period of one year in 1996-97. They measured wind parameters at a height of 25 m [2]. At present, several wind resource works is ongoing in the country by Bangladesh Power Development Board (BPDB), Bangladesh Council of Scientific and Industrial Research (BCSIR), Local Government Engineering Department (LGED) and Bangladesh University of Engineering and Technology (BUET). They have already started measuring wind speeds at some typical locations of Bangladesh. In Bangladesh firstever generation of electricity from wind is at Muhuri Dam, Feni having a capacity of 0.9 MW (225 KW, 4 Turbines) and another one at Kutubia Island (20 KW, 50 turbines) with a capacity of 1 MW [3]. Vesta Company of Denmark will invest 100 MW wind power plant which will be made in Patuakhali. This will be the largest wind power plant of Bangladesh [6]. Bangladesh is situated between 20.30 - 26.38 degrees North latitude and 88.04 - 92.44 degrees East [3]. Analysis of upper air data by Center for Wind Energy Technology (CWET) India shows that wind energy resource of Bangladesh for electricity production is not good enough (< 7m/s) in most of the region of the country for grid connected wind parks. This sector is under research mainly at coastal zone [28, 21]. Bangladesh has a total of 574 km long coast line in the Bay of Bengal. The strong south/south-westerly monsoon wind coming from the Indian Ocean, after travelling a long distance over the water surface, enters into the coastal areas of Bangladesh. This trade wind blows over the country from March to October.

Project Name	Capacity	Location	Completion Date	Present Status
1000 kW Capacity Wind Battery Hybrid Power Plant	1 MW	Kutubdia Upazila, Cox's Bazar	2015-12-31	Completed & Running
1000 kW Capacity Wind Battery Hybrid Power Plant	1 MW	Kutubdia Upazila, Cox's Bazar	2008-12-31	Completed & Running
Feni Wind Power Plant	900 KW	Sonagazi, Feni	2006-09-27	Completed & Running

LITERATURE REVIEW

Niranjana. S.J [1] Inquired to generate power by fixing the vertical axis wind turbine on the highways. This paper indicates that the vertical axis wind turbine can be able to generate 1KW of power when it moves at 25m/s.

Abhijit N Roy [2] et al. tried to design and fabricate and economical vertical axis wind turbine. In this experiment, the shaft of the rotor is connected vertically to the wind turbine with the generator. It uses a gearbox that can be fixed near to the ground.

D.A. Nikam [3] et al. reviewed the literature and development of the blade of the vertical axis wind turbine. This paper indicates the characteristics and advantages of both HAWT and VAWT. The experimental outcome of this paper tells that design of the blade plays an essential role in the performance of the turbine. A modified blade can improve the efficiency of the wind turbine.

Altab Hossain [4] et al. showed a design that investigated the development of vertical axis wind turbines. The blade and the drag devices are designed in such a way that they are at a ratio of 1:3 to the wind turbine. The calculated output if this experiment is it produces 567W and 709W power when the wind speeds are 20m/s and 25m/s, respectively.

Parth Rathod [5] et al. analyzed the efficiency of a vertical axis wind turbine by combining their rotor. In this experiment, higher efficiency is achieved compared to the single savonious and darries rotor. The outcome of this paper shows that turbine efficiency depends on wind speed and environmental conditions.

Kunduru Akhil Reddy [6] et al. researched to increase the aerodynamic efficiency of the wind turbine. Blades are designed by using various types of airfoils that are attached to the angle of attack.

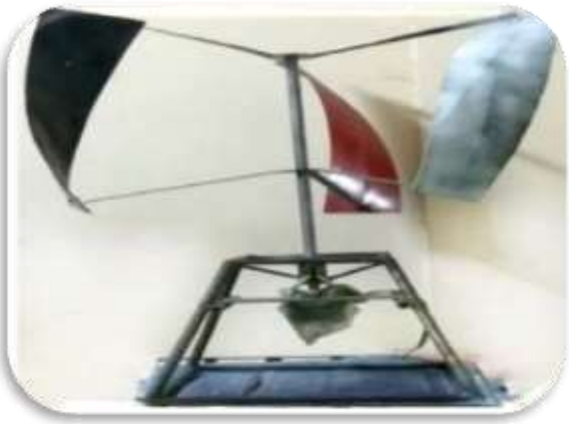
PiyushGulve [7] et al. raised the design and construction of vertical axis wind turbines. This paper discussed the advantages of VAWT over HAWT. This paper indicates that the lea error on manufacture and friction loss, the higher efficiency. This loss can be minimized by designing the blades more aerodynamically.

M. Abid [8] et al. has shown a design and develop a model to test both savonius and darrieus axis wind turbine and found VAWT is more efficient over HAWT. The testing result indicates darrieus VAWT acts as a self-starting wind turbine that operates at low speed.

Aim of work

The work in this thesis aims to take a closer look at the eigenfrequencies of a semi-guywired wind turbine tower as well as the characteristics of the noise emitted from a VAWT. This should be done by performing theoretical and analytical studies as well as computer simulations and experiments. In this thesis, the theory, results and conclusions is presented in such a way that the scientific contribution is pointed out. The purpose for studying the VAWT concept is to better understand its future chances of being an alternative to HAWTs. Further learning of the advantages and disadvantages of the concept can also help to find application areas that are especially suitable for VAWTs. Also, by drawing knowledge from existing VAWTs, the possibilities for building well-functioning turbines in the future increases.

Figure 1: Comparison with Previous Work



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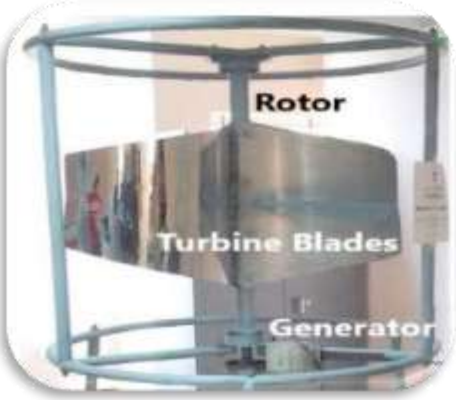

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BD Highway Turbine

Theory

Eigenfrequencies of vertical axis wind turbines

An eigenfrequency is a frequency at which a construction tends to oscillate in the absence of driving or damping forces. If the eigenfrequency coincide with a forced frequency, a so-called dynamic load, the amplitude of vibration escalates and a so-called resonance occurs. A construction has several different eigenfrequencies, different modes, where for each frequency the construction is moving in a different way. In figure 2.1 the first four mode shapes for an unsupported cylindrical tower attached to the ground can be seen. Eigenfrequencies of a structure depend on material, shape, height, mass as well as motion constraints such as guy wires.

Instability due to eigenfrequencies are of concern regarding wind turbines as well as most other tall structures. Different components of a wind turbine can have their own eigenfrequency and besides the tower which is the main subject of this work, the T1turbines mode shapes due to the elasticity of the struts has been examined in and for the driveshaft in. In it was found that by careful dimensioning it is possible to obtain a large resonance free operational rotational speed range regarding the struts. The aerodynamic damping of the eigenmodes of interest was also found to be good. In it was found that by using a directly-driven generator the shaft can be made considerably smaller. Furthermore, the Sandia National Laboratories VAWT research of the 1970-80s includes work on guyed VAWTs, for example vibration and damping issues of the guy wires. Sandia studies a Darrieus turbine supported entirely by guy wires attached to the top, whereas the VAWT studied in this work is only partly guy wire supported.

For the tower of a typical wind turbine it is mainly the first mode eigenfrequency that is of interest since it may coincide with a dynamic load of the turbine. The dynamic loads of significance are imbalances in the shaft or rotor as well as aerodynamic loads of the passing blades. The frequencies of these loads are 1P and 3P respectively, where P is the rotational speed of the turbine.

When designing a wind turbine tower different strategies can be used to avoid the dynamic loads. The tower can be made stiff which means that the eigenfrequency is placed above the 3P load for the entire operational range. The tower can also be made soft which means that the eigenfrequency is placed between the 1P and 3P or even soft with the eigenfrequency placed below the 1P load. In figure 2.2 these strategies for an operational range typical for a modern 3MW HAWT can be seen. For the soft and soft-soft towers the eigenfrequencies are briefly excited when ramping up rotational speed during start up but are not located within

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the operational range. For modern large scale turbines soft towers are the most common, this because it usually is a good trade of between stability and economy.

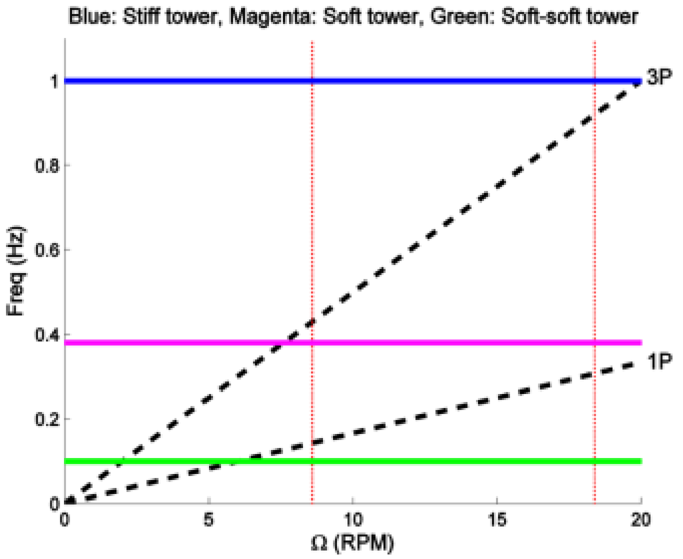

Figure 2: A Campbell diagram showing a stiff tower (blue), soft tower (magenta) and soft-soft tower (green). Operational range marked with red dashed lines.

First mode eigenfrequency of a semi-guy-wired tower

For a typical freestanding tower the first mode eigenfrequency can be approximated by using a fairly straightforward expression (1) for a vertical weightless uniform beam of length H, with the lower end attached to the ground and a point mass m attached to the top [17]. Where Et is the elasticity modulus of the tower material, and I the second moment of area of the beam. However, the T1-turbine is a near unique case since it was freestanding from the start but since has been complemented with guy wires thus making it both firmly bolted to the ground and constrained at a certain height by the guy wires – hence there is no suitable ready-made expression available to use. If the guy wires are attached to the tower at height h, a force has to be included that counteracts the tower movement, making the frequency calculation more complex. The net force from the guy wires can be divided into z- and x-components, Fz and Fx, where the verticaly acting Fx can be neglected due to its minimal effect on the tower movement for small deviations.

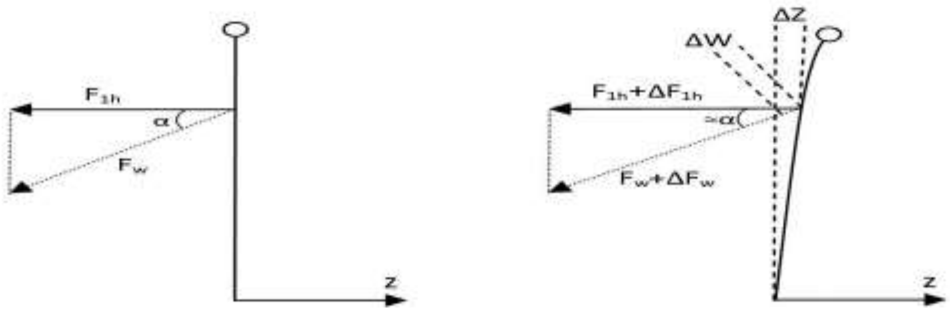

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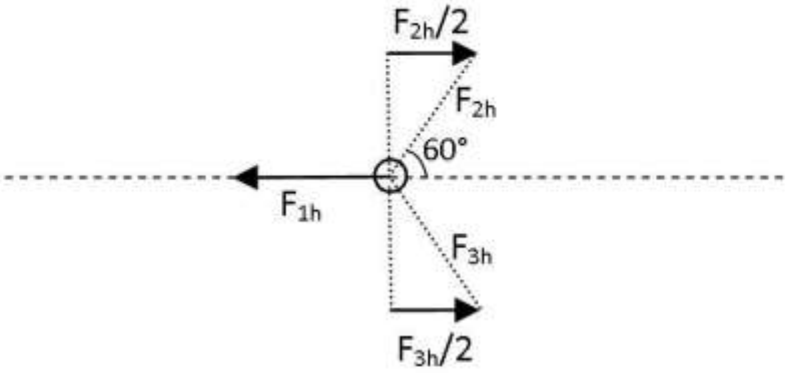
Figure 3: The tower modeled as a weightless uniform beam with a mass m on top. H is the height of the tower, h is the height of guy wire attachment point and z is the horizontal deviation.



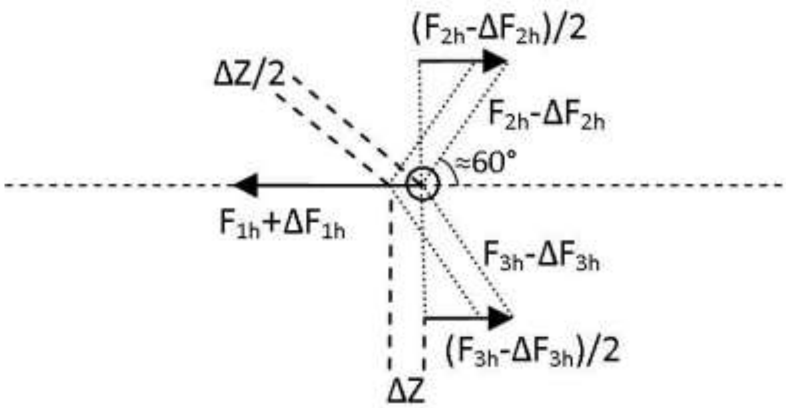


Figure 4: Spring forces seen from side. Left: Forces acting when in rest. Right: Forces acting after displacement.

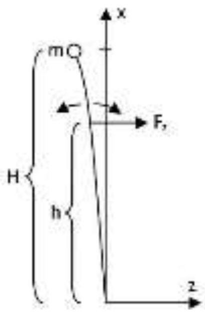


Figure 5: Spring forces seen from above. Upper: Forces acting when in rest. Lower: Forces acting after displacement.

METHODOLOGY

Constructed Savonious Rotor VAWT

The blade, rotor and main structure of the proposed VAWT are designed very simply so that it can be scaled up easily. The designed turbine is shown in Fig.1. The total height of this turbine is 4 feet. Whereas, the blades and main wide area consist of 1.75 feet. The tower structure is made by using the GI pipe. the top view of this design is shown in Fig.2 with all dimension parameters.

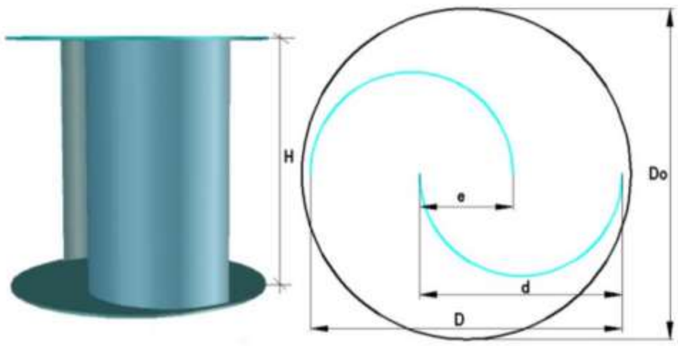


Figure 6 – Top view of the designed VASWT

Table 2 shows the constructive sizes of the Savonius rotors VAWT used for the test.

Table 2 – Turbine Size

Parameters	Value
Total Height	141cm 4.62598 feet
Total Wide	53.34cm 1.75 feet

It contains two bearings located at the top and the bottom. The rotor contains the three blades which are replaceable by different shaped blades confining in the rotor size. The blade is shaped from the steel. The turbine blade is needed to be light enough to move with the force of the air. At the same time, it should be strong enough to remain unbent and oppose excessive force. For this reason, the SS steel sheet was used to construct the blades. Stainless Steel (SS) sheet is very useful in the conditions of the coastal regions because it is free from getting rusted. The blades are attached to the rotor confining in a size to be inside the tower structure. Table 2 shows the VASWT blades specifications.

Table 3 - VASWT blades specifications

Parameters	Value
Blade diameter, d	20.32cm

Bending angle	45 degrees
Blade length, L	76.2cm
Blade Thickness	0.4cm
Total Blade	03
Blade martials	Plastic

Description of the Proposed Model

The block diagram of our model shows the overview of how it works to generate electricity effectively. Here electrical power generated by the respective systems is given to switching circuit. By comparing the battery voltage with both the inputs the controller gives signal to switching circuit to select appropriate input which used to charge the battery through pulse width modulation (PWM) controller.

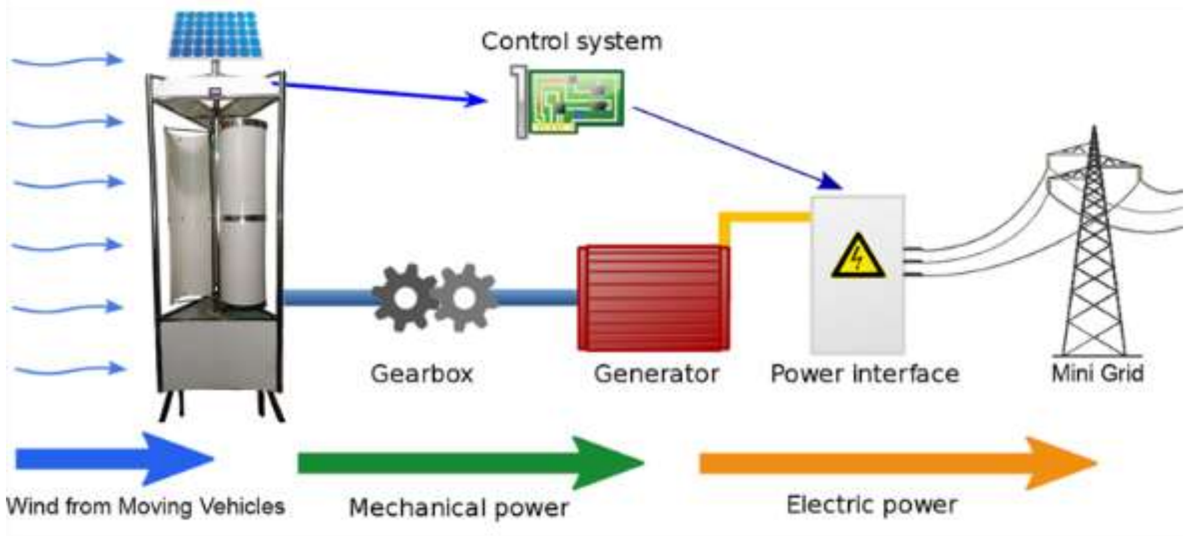


Figure 7 :Block Diagram of Proposed Model

Solar Panel

Solar energy is green energy which is easily available in day time. We can generate electricity by using PV cell. It is huge source of never-ending energy. Because of easily availability, amount of source and popularity it is preferred for this model. Solar panel contains photovoltaic material which generate electrical energy when sun light falls on it. Depending upon the light intensity and position of the sun radiation the output electrical energy will be generate. The given model have one Polycrystalline type solar panels are used because their efficiency is greater than other which is 14-16 per cent. The specification 10W, 17.5V, 0.64A each is used. In this model two solar panel are mounted on top of the pole. The output of solar panels is given to battery through PWM charge controller.

Generator and Gear Ratio Selection

Though the rotation speed of the vertical axis wind turbine is lower it has higher torque. Using a gear system is essential to get a higher rpm in the rotor shaft of the generator. Fig.4 shown in Proposed gear system For higher torque, the rotor to generator ratio can be kept 4:1. Here in big gear have 60 teeth and small gear have 15 teeth.

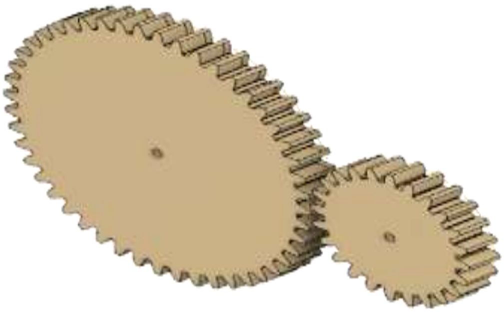


Figure8: Proposed gear system

1 KW capacity DC generator is used to convert the extracted mechanical power to electrical power Fig.5. This generator is connected with the rotor by a belt. The output of this generator is fed into the load. Table III shows the specification of the DC generator.

Motor Generator Specification

Parameters	Value
Capacity	1000W
Speed	1400 RPM
Output DC Voltage	6V, 12V, 24V
Motor	3 phases current PMSG
Working temperature	-40℃~80℃
Main motor weight	7 Kg

Figure 9: Printed Circuit Board (PCB)

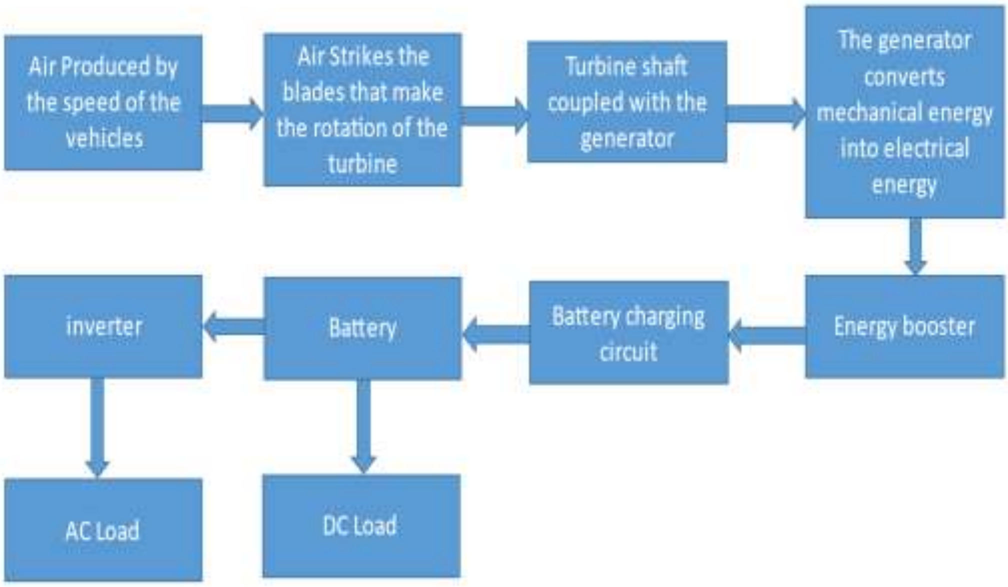


Figure 10: Block Diagram of the Proposed System

Figure 11:Motor Connection with Gear

How is it working?

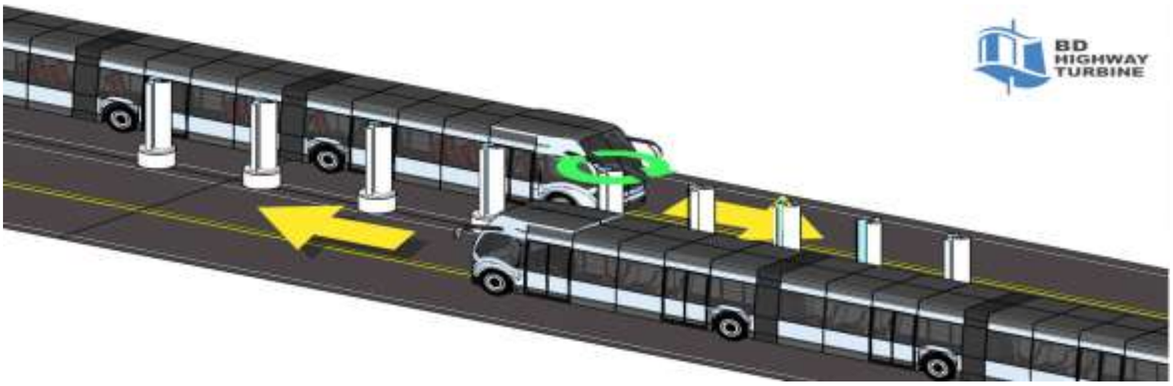


Figure 12: Materials for Turbine

Figure13: Feature

Advantages

RESULT

As the model is design mainly for highway applications so we take a wind survey on Mumbai- Goa highway and placed model on highway divider. For testing purpose by using external fans we produced the air of required speed and measured turbine speed. The voltage generated is also measured with respect to variation in wind speed. The following table shows the results come out from turbine. We used the gear ratio of 1:25 to achieve the rated 750 rpm of generator when turbine rotates at 30 rpm. To get the higher speed of 750 rpm we used 4 gear mechanics. According to test performed and the survey of wind generated on highway by moving vehicles, the operating time of wind turbine on average is 4 to 5 hours in a day at full rated output. The switching take place between solar and wind turbine according to voltage generated by them. Hence, the charging time required to charge the battery to full is reduced as compare to stand alone system.

CONCLUSION

This hybrid model of VAWT and solar on highways have good source of green power. Present work of model experimentally shows the hybrid wind and solar power generation can be used to generate large amount of power at almost all time of day. This can be an alternative source of energy to the non- renewable resources. By using this model all the highways and small villages can be lighted without the use of conventional energy sources. This can be implemented instead of single source, to gain more power almost at all times. Finally, conclude that this paper can give electricity without pollution to many highways and small villages.

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