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DESIGN AND ANALYSIS OF VERTICAL AXIS TRAFFIC WIND TURBINE

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***Abstract* - The principal objective of this project is Power generation via a hybrid system that includes wind and solar energy. Our intention is to design a wind turbine compact enough to be installed on the roadside. So we decided to design a vertical axis wind turbine (VAWT) over Horizontal Axis Wind Turbine (HAWT). Advantages of VAWT over HAWT are compact for the same electricity generation, less noise, easy for installation and maintenance and reacts to wind from all directions. The wind turbine is designed to generate electricity sufficient enough for a power direction. The electricity generated will be stored in the battery and then given to the load. This project emphasizes electrification to charge the batteries of electric vehicles with minimum cost. 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 energy is unused. Extensive research on wind patterns is required to determine the average velocity of the wind created by oncoming vehicles. The wind turbines will 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. Additionally, since the wind source will fluctuate, a storage system for the power generated will be 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.**

***Keywords* –** Vertical axis wind turbine, Kinetic energy of wind, Darrieus Turbine , Highway medians.

I. INTRODUCTION

Wind energy is the fastest-growing source of clean energy worldwide. 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 toward clean energy in a feasible way. DESIGN CHALLENGES The price of turbines is increasing in accordance with the rising cost of energy and commodities. The cost of designing the turbine, calculated in energy savings must be recovered in a reasonable time period. Each vehicle on the highway offers an intermittent and uncontrolled source of wind power. The design of the wind turbine must include storage of power and a system to distribute the generated power effectively. Wind turbines are traditionally used in remote locations. This offers the additional challenge of having to transport the power generated to the location wherein it will be utilized. Fortunately, the wind turbine in this project is designed for use in high traffic areas where the demand for power is high. Safety is another major design consideration. The turbines must be placed in high traffic areas therefore several safety provisions are incorporated into the design. These safety measures include stationary highway guards surrounding the rotating turbine blades and warning labels. Wind power devices are used to produce electricity and are commonly termed wind turbines. The orientation of the shaft and rotational axis determines the classification of the wind turbines. A turbine with a shaft-mounted horizontally parallel to the ground is known as a horizontal axis wind turbine (HAWT). A vertical axis wind turbine (VAWT) has its shaft normal to the ground.

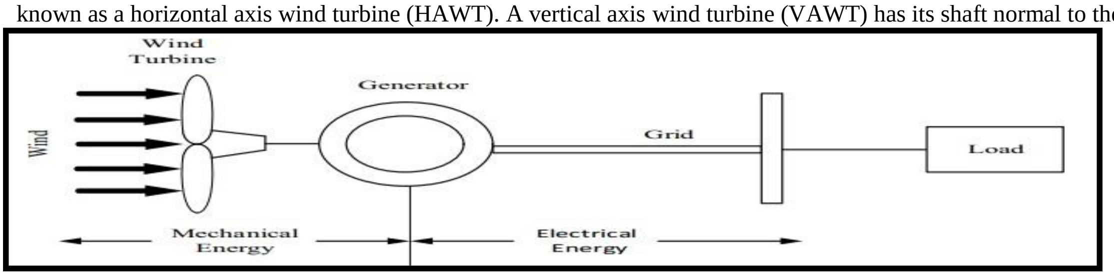


Fig.1 Working of VAWT

II. TYPES OF WIND TURBINE

There are generally two types of wind turbines

1. VAWT - Vertical Axis Wind Turbine

   The VAWT is a turbine in which the axis of rotor is perpendicular to the wind stream and the ground. VAWT commonly function nearer to the ground, and has the benefit of enabling placement of heavy equipment, such as the gearbox and generator, close to the ground level and not in the nacelle. However, the winds are lower near ground level hence for a similar wind and capture area, a less amount of power is generated. Another benefit of a VAWT is that it does not need a yaw mechanism, because it can harness the wind from all directions. This benefit is outweighed by numerous other limitations, such as: time varying power output because of change of power in a single blade rotation, the requirement for guy wires to support the main tower and the fact that the Darrieus VAWT are do not self-start like HAWTS.

2. HAWT - Horizontal Axis Wind Turbine

   The horizontal wind turbine is a turbine in which the axis of the rotor's rotation is parallel to the wind stream and the ground. Most HAWTs today are two- or three-bladed, though some may have fewer or more blades. The HAWT works when the wind passes over both surfaces of the airfoil shaped blade but passes more rapidly at the upper side of the blade, thus, creating a lower-pressure area above the airfoil. The difference in the pressures of the top and bottom surfaces results in an aerodynamic lift. The blades of the wind turbine are constrained to move in a plane with a hub at its center, thus, the lift force causes rotation about the hub. In addition to the lifting force, the drag force, which is perpendicular to the lift force, impedes rotor rotation.

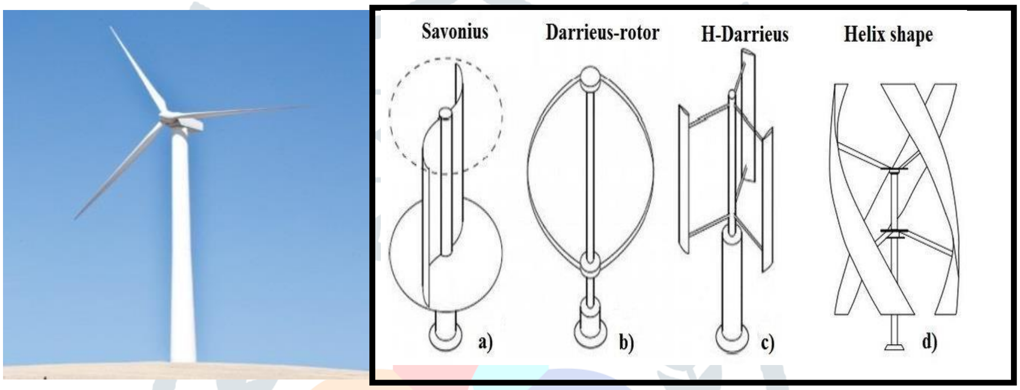


Fig. 3 HAWT and VAWT

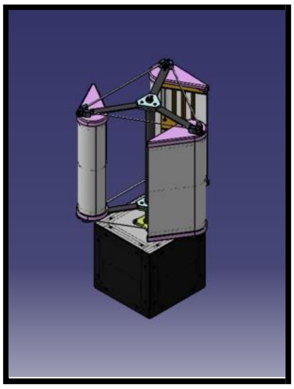
III. WIND TURBINE SELECTION

We used an open-source database available online from the Open Energy Platform (OEP) for a library of 68 turbines from the leading turbine manufacturers. The data constitute nominal power, rotor diameter, swept area, and power curve values (i.e., wind speed vs. output power). The figure shows the power curves of all turbines with diverse nominal power, cut-in, and cut-out values. The International Electro technical Commission (IEC) has widely established accepted standards Appl. Sci. **2020**, 10, 5654 5 of 13 for wind turbines, including the determination of the measured power curves. Commonly, the power curve of the wind turbine is represented using the average wind speed with intervals of 0.5 m/s.
In this study, the wind speed intervals (bins) of all wind turbine power curves were limited to 0.5 m/s. To select the turbines that show minimal variations in output power within a specific time interval (e.g.21 min), we conducted a statistical analysis of the annual wind speed data. For each time interval window, the output power was constrained to have a standard deviationof less than 0.1 kW. The wind turbine with the highest total annual time intervals with constant power was selected for the analysis in this study. The equations involved in this calculation are detailed in the following subsection. The International Electro technical Commission (IEC) has widely established accepted standards for wind turbines, including the determination of the measured power curves. Commonly, the power curve of the wind turbine is represented using the average wind speed with intervals of 0.5 m/s. In this study, the wind speed intervals (bins) of all wind turbine power curves were limited to 0.5 m/s. To select the turbines that show minimal variations in output power within a specific time interval (e.g.21 min), we conducted a statistical analysis on the annual wind speed data. For each time interval window, the output power was constrained to have a standard deviation of less than 0.1 kW. The wind turbine with the highest total annual time intervals with constant power was selected for the analysis in this study. The equations involved in this calculation are detailed.

Turbine Design-

The VAWT (Vertical Axis Wind Turbine) is 4 feet tall and 3 feet in diameter. It is basically a Savonius-style turbine but with the refinement that the three wings are shaped to provide lift as well because of their teardrop configuration. This turbine is more efficient than a pure Savonius in that it provides both drag and lift.
In our design, we scaled down the diameter to approximately 18 inches and the height to 21 inches. (In hindsight, I shouldhave made the height 18 inches so that there would be more of the center axis free on both ends for flexibility in mounting.) H-Darrieus turbine (Type H-rotor) can be characterized by straight panels which, together create the letter H. It hasimproved efficiency, simpler construction, and

relatively high-power units. The rotor aerofoils are spaced up from the centerof the turbine so that the rotation continuously changes the attack angle relative to the wind. However, when one of theblades is operated with the wind, the second opposed resists. This in consequence reduces the efficiency of the design. Tipspeed ratio of the turbine described is between 0.8 and 1.2 at wind speeds of 6.7 m/s. This means that the turbine uses the liftforce. The rotational speed of the turbine should be approx. 130 r / min.



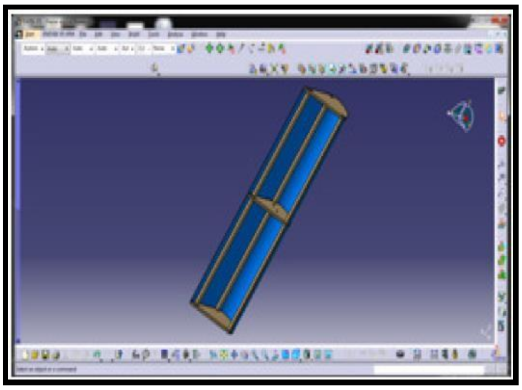


Fig. 4 Turbine Blades

IV. CALCULATIONS

IV. I. POWER CALCULATIONS

Power can be defined by the formula P= 1/2ρAV^3

Where, P = power output ρ = *Air density* = 0.00508V = Wind velocity = 40kmph

A = Area of turbine = h * d = 1.21 * 0.91

Considering turbine efficiency as 41% and generator efficiency 75%,

P= ½ ϱ AV^3

P = 0.00508 * (1.21 * 0.91) * (40)^3 * 0.41 * 0.75

P = 110.08 Watt

IV. II. WING CALCULATION

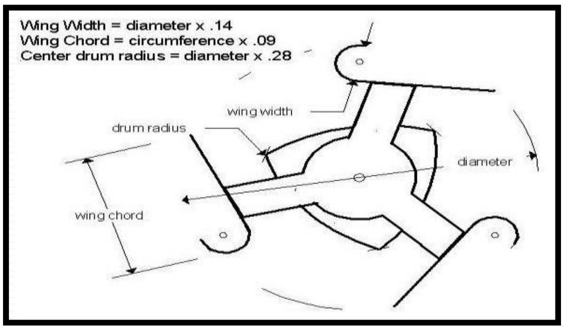


Fig. 5 Turbine reference

Wing width = dia. * .14,

= 6.76*.14

= 0.270 m

Wing chord = circumference*.09

= 2*π*r*.09

= 1.911 m

Centre drum radius = dia.* .28

= .9*.28

= .252 m

V. SIMULATIONS

Leaving the core design: shaft, hub bearings, stator, and the rotors, developed a second model type Lenz2. Darrieus turbine using the lift is very efficient compared to the turbine Savonius but has problems with self-start. While Savonius's turbine has trouble-free start it does not reach higher speeds, so the Lenz2 model seems to be the ideal solution, combining the two concepts.

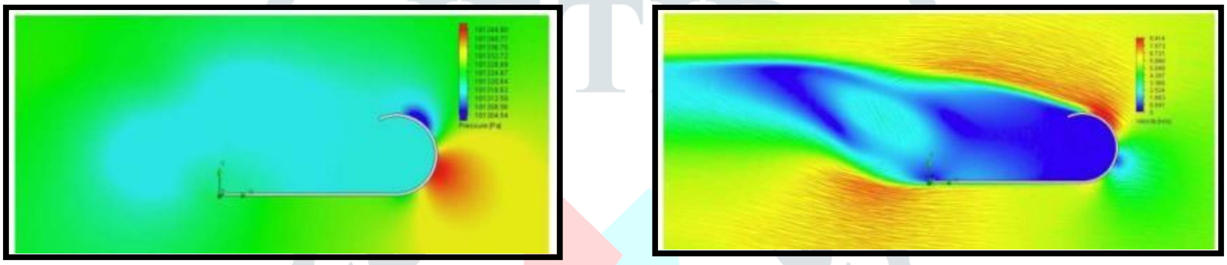


Fig. 6 Pressure Distribution and Speed Distribution

VI. CONCLUSIONS

- Conclusively, extensive data is collected on wind patterns produced by vehicles on both sides of the highway.
- Although one turbine may not provide adequate power generation, a collective of turbines on a long strip of highway has the potential to generate a large amount of energy that can be used to power and street Lights, and other public amenities.
- Traffic wind turbines 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.

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