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Design and Fabrication of Vertical Axis Wind Turbine

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Abstract: Wind energy is the most available form of renewable energy among all the energy sources. Wind energy can be extracted by a wind turbine and can be converted into electrical energy using proper electricity generating apparatus. This paper is focused on a technique that can be used effectively for the purpose of converting the kinetic energy of wind into electrical energy. This process is completely friendly to environment and the cost associated with the fabrication is very little. In this research a vertical axis wind turbine has been designed and fabricated to perform the job of extracting energy from wind. The turbine is of Darrieus type with three twisted blades. For the conversion of mechanical energy from the turbine into electric current an alternator also fabricated and coupled with the turbine. This paper describes the whole procedure to build up a simple wind power system with vertical axis wind turbine and shows performance of such power system under various wind speed. The specialty of this system is its extremely simple arrangement and absence of any motion transmission

I. INTRODUCTION

People have been harvesting wind for mechanical power since the 9th century when Persians created vertical-axis windmills to grind grain. Windmills continued to flourish and were developed into what we now know as horizontal-axis windmills. They were widely used during the late medieval and early modern times. With the introduction of fossil fuels such as coal and oil, the utility of windmills declined dramatically.

However, the growing demand for electricity and the invention of the first airplane created an interest in the science of aerodynamics and as a result in other wind-driven machines as well. Between the years of 1888 and 1900, the United States and Denmark conducted experiments on the use of the mechanical structure of windmills for the generation of electricity. Consequently, this resulted in the development of the first wind turbines. Two decades later, the Finnish engineer Sigurd Johannes Savonius invented the Savonius-style wind turbine (SSWT).

The initial rotor was not designed to generate electricity but instead designed to power ships. Sigurd Savonius aimed to take advantage of the Magnus effect by placing a vertical axis rotor on a ship and create a propulsion effect pushing it forward. Later on, the Savonius rotor was developed further and in 1926 a patent for an SSWT generating electricity was filed. However, SSWTs have been explored long before the 1920s and the first records of similar designs date back as early as the 17th century.

Nowadays when discussing Savonius rotors in the field of wind energy, the term refers to a subdivision of vertical-axis wind turbines. A common characteristic of SSWTs is that they consist of two or more blades symmetrically placed around the vertical rotational The SSWT can be designed to be very compact in size and can, therefore, be integrated into urban spaces, for example by being placed on rooftops, sign-poles, and statues. The UK start-up company Capture Mobility gives another great example of an implementation for the SSWTs.

The company developed a small-scaled SSWT that would produce up to 1kW of electricity per turbine from the turbulence of passing cars near highly trafficked roads. The produced electricity could be used to power streetlights and road signs Europe has an excellent reputation in supporting renewable energy sources and had accounted for over 70% of global wind power installations by 2000. In 2009 the Swedish Parliament decided to set a goal of at least 50% of the total energy usage coming from renewable energy sources by 2020.

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II. LITERATURE REVIEW

Mohammad Hadi Ali, ‘‘Experimental Comparison Study For Savonius Wind Turbine ofTwo & Three Blades At Low Wind Speed”, International Journal Of Modern Engineering Research (IJMER) Vol.3, Sep-Oct .2013
Mohammed Hadi Ali Has carried out experimental comparison and investigation ofperformance between two and three blades wind turbine. Due to this purpose, two models of two and three semi-cylindrical blades were designed and fabricated from Aluminium sheet, with having an Aspect ratio of (As = H/D =1), the dimension is (H = 200 mm height and diameter D = 200 mm). These two models were assembled to have overlap zero (e = 0) and a separation gap zero (e' = 0). Subsonic wind tunnel is used to investigate these two models underlow wind speed condition, which shows that maximum performance at (λ = TSR = 1) and a high starting torque at low wind speed, and also gives reason for three bladed rotors is more efficient than the two blades, that by increasing the number of blades will increase the drag surfaces against the wind air flow and causes to increase the reverse torque and leads to decrease the net torque working on the blades of wind turbine.

Shrikant G. Gavde, Prof. D.S.Patil,‘‘Comparative Study Of A Single Stage Savonius With A Combined Savonius-Three Bladed Darrieus”,International Journal For Technological ResearchIn Engineering Volume 2, February-2015 .
ShrikantG.Gawade,D.S.Patil Has conducted comparative study of a single stage Savoniuswith combined Savonius- 3 blade Darrieus. For maximum power output NACA0021 blade profile for H-rotor is taken in to consideration. From experimental study it was concluded, themaximum power co-efficient for single turbine is around 16% while for combined multiple rotor has maximum power co-efficient is 39% which is much more improved towards power production.

S Brusca, R Lanzafame, M Messina.**S Brusca, R Lanzafame, M Messina, international journal of energy and environmental engineering 2 August 2014**
This experiment work looks at designing a vertical-axis wind turbine to maximize its power coefficient. It has been seen that the power coefficient of a wind turbine increases as theblade’s Reynolds number rises. By experimental study it was found that the ratio between bladeheight and rotor radius (aspect ratio) influences the Reynolds number and as a consequence thepower coefficient. It has been highlighted that a turbine with a lower aspect ratio has several advantages over one with a higher value. The advantages of a turbine with a lower aspect ratioare higher power coefficients, a structural advantage by having a thicker blade (less height andgreater chord) and greater in-service stability from the greater inertia moment of the turbine rotor.

M. ZEMAMO Ua, M. AGGOU Ra , A.TOUMI. 4th International Conference on Powerand Energy Systems Engineering, CPESE 2017, 25-29 September 2017, Berlin, Germany
The Savonius rotor has proven its performance due to its simple design, low cost and low starting torque at low wind speed despite its low efficiency caused by the negative torqueapplied to the returning blade, for years several research aim to improve the design of Savonuisrotor in order to achieve better performance. This paper aims to compare several results of published articles on performance of new designs of Savonius rotor. It is intended to provide an important background for future studies on this type of wind turbine. According to this review result we conclude that over the years, the development of the shape of Savonius rotorblade remains a very promising research field in order to improve the performance of the rotor,It is perceived that research on parameters such as AR, overlap ratio and number of blade canbe more studied to arrive at a satisfactory level of performance, although adding an extra set like obstacle shielding, curtain or conveyor deflector improve the performance of Savonius these developed designs of Savonius have made this rotor system very complex and dependenton the direction which represent a major drawback of this studies, in this context the search fora compromise between rotor efficiency and system simplicity is a promising area of research for future works.

III. WORKING

The Savonius wind turbine is a simple vertical axis device having a shape of half- cylindrical parts attached to the opposite sides of a vertical shaft (for two-bladed arrangement) and operate on the drag force, so it can’t rotate faster than the wind speed. This means that the tip speed ratio is equal to 1 or smaller. As the wind blows into the structure and comes into contact with the opposite faced surfaces (one convex and other concave), two different forces (drag and lift) are exerted on those two surfaces.

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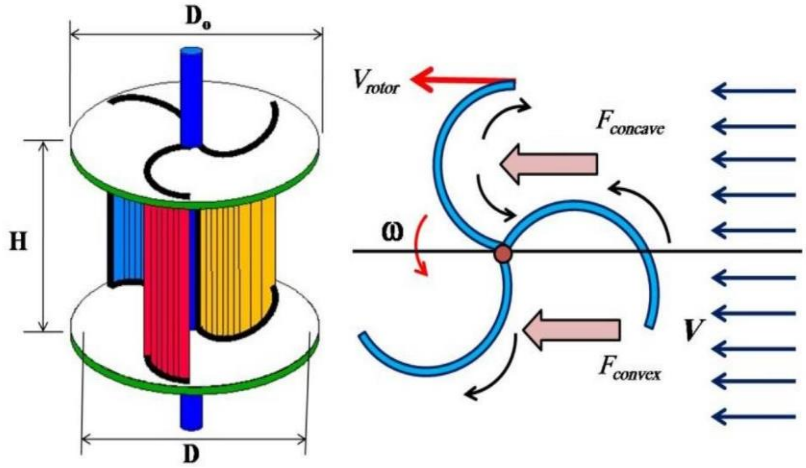

The basic principle is based on the difference of the drag force between the convex and the concave parts of the rotor blades when they rotate around a vertical shaft. Thus, drag force is the main driving force of the savonius rotor. The dynamic analysis of its operation shows the influence of lift force. The Savonius can't really be classified into one or the other of these categories. Its efficiency at starting is in fact mainly due to drag force, but its maintenance in rotation is mainly due to the force of lift.

IV. METHODOLOGY

The goal of this project is to develop a design for a cheap but effective wind turbine. The turbine must have a cut-in speed no greater than 5 m/s, produce at least 10 watts, and be created from at least 75% recycled material. The design must also be repeatable by someone with only moderate technical skills. This allows our project to reach our target demographic of off-grid communities, developing countries, or areas recently affected by natural disasters. To meet these objectives we identified the following tasks to be completed:

- Select turbine type
- Make a conceptual diagram
- Select component
- Develop method for testing the turbine's performance
- Construct turbine from components
- Test the turbine

Selection of Turbine Type:
The first step in the design process was to determine whether a vertical axis turbine (VAWT) or a horizontal axis turbine (HAWT) best suited our application. To do this, we compared typical torque, tip speed ratio, coefficient of power, and cut-in speed values for each design. We also looked into previous at home DIY turbine designs as well to see whether one 26 type of turbine required less skill to create or if one type performed better than the other. From our research we determined that both types of turbines have their own sets of advantages and disadvantages; however, in the end it was decided that a vertical axis turbine would best suit our needs.

Table 1: Comparison of characteristics between HAWT and VAWT

Characteristic	HAWT	VAWT
Tip Speed Ratio	6	<1 to 3
Torque Output	Low Torque High RPM	High torque Low RPM
Cut-in Speed	5 m/s	2 m/s to 5 m/s
Coefficient of Power	~0.40	0.15 to 0.4
Yaw System	Requires Yaw System	Does not Require Yaw System

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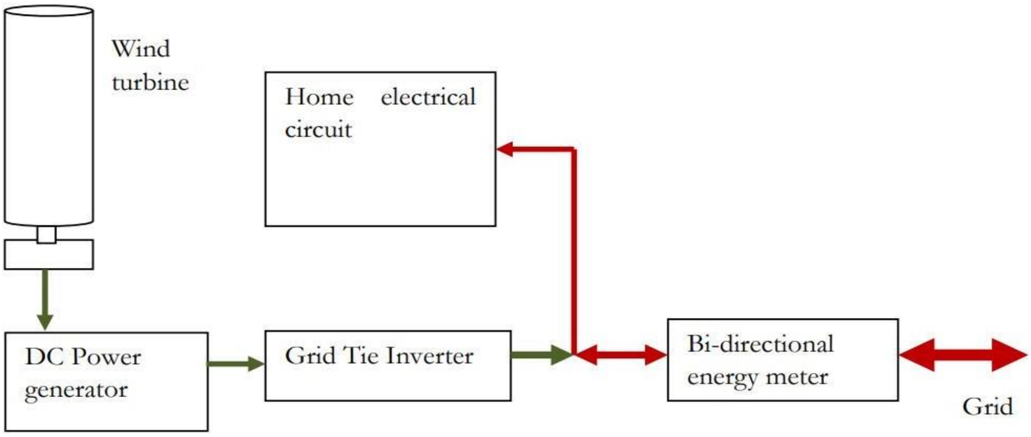
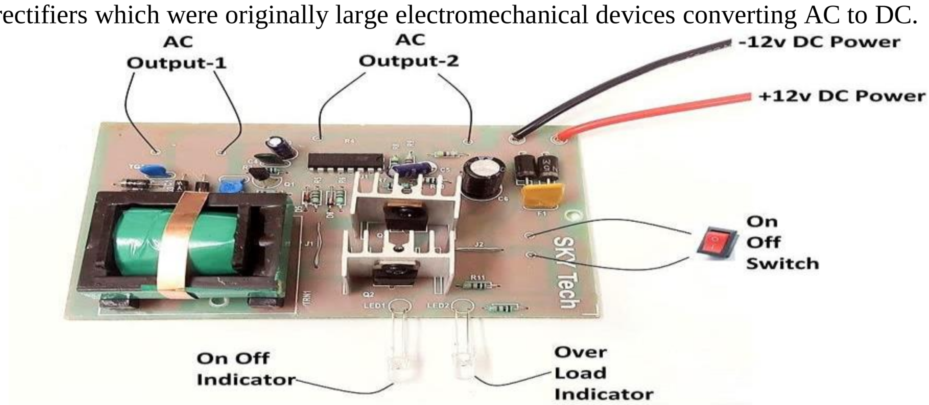
Based upon our findings, as seen in Table 1, we concluded that a Vertical Axis Turbine best suited our design application. This decision was made for a variety of reasons. First, we wanted our turbine to produce electricity in low wind conditions (wind velocities between 5- 10 knots or 2.6-5.14m/s). This would require the turbine to produce enough torque to spin the motor. Vertical axis turbines are best suited for these conditions because they can have cut-in speeds at the low end of our desired range. They also typically produce larger amounts of torque which would allow our motor shaft to spin and generate electricity.
Once we chose to construct a vertical axis turbine, the next step was to determine which model best suited our application. From our research we identified three potential models: Darrieus, Savonius, or Hybrid. In order to pick the best design, we compared the characteristics of each model to determine which one best suited our intended design criteria. The comparison can be seen in Table 2. We concluded that the Savonius model was a poor choice for our application. While Savonius turbines are self-starting, easy to construct, and have low cut-in speeds, the tip speed ratio was too low.

Block diagram:



Net metering is a utility policy created to facilitate consumers who own alternative energy source converters, especially renewable energy systems, and who want to export excesselectricity to the national grid. The word "Net" refers to that consumers pay only for the net power they consumed when locally produced electricity is measured against the consumed such. More accurately, in the net metering system the grid acts as a large energy storage, accepting the locally produced power whenever it is available and delivering power wheneverit is needed and when local.
More accurately, in the net metering system the grid acts as a large energy storage, accepting the locally produced power whenever it is available and delivering power wheneverit is needed and when local production is insufficient. The consumers only pay for the net amount of energy they imported from the grid.

Inverter circuit:
A power inverter, inverter or invertor is a power electronic device or circuitry that changes direct current (DC) to alternating current (AC). The resulting AC frequency obtaineddepends on the particular device employed. Inverters do the opposite of rectifiers which were originally large electromechanical devices converting AC to DC.



A power inverter, inverter or invertor is a power electronic device or circuitry that changes direct current (DC) to alternating current (AC). The resulting AC frequency obtaineddepends on the particular device employed. Inverters do the opposite of rectifiers which were originally large electromechanical devices converting AC to DC.
We use 12V DC to 220V AC inverter circuit. This circuit is designed using IC CD4047.The IC CD4047 acts as a switching

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pulse oscillating device. The n-channel power MOSFET IRFZ44n acts as a switch. The 12-0-12V secondary transformer inversely used as a Step-up transformer from converting low AC to High Ac

V. RESULT

The data collected during the testing phase of this project illustrates that the development of a turbine from recycled and repurposed material is feasible. All testing were taken on highway road. Collected all data is taken when the vehicles are passes near the turbine. We take more than 100 trials and after that came on conclusion which is given below. In general, the turbine's performance was similar to the response predicted by our initial simulations. However, due to the assumptions made in the initial simulation and the limitations in the data collection process there are differences between the predicted turbine response and the actual values obtained from the turbine.

VI. CONCLUSION

The turbine developed in this project is a proof of concept. With the proper charging circuit, the turbine could be adapted to charge small electronic devices such as battery packs or cell phones. While we were successful in designing and building a turbine that required little machining, it did not meet the electrical output we desired. We had expected the turbine to produce 20W of power but the maximum power achieved during testing was 10W. Future improvements can be made to not only improve the performance of the turbine but also the accuracy of the data recorded. We used a laser tachometer to measure the RPM of the turbine, but at times the tachometer could not accurately record RPMs because of the reflection from the sun. Using a contact tachometer to measure the RPMs would remove any variations in the measurements caused by the sun, giving us more accurate readings. Additionally, we used a simple unidirectional anemometer to measure the wind speed, but the area we tested the turbine had intermittent, and different wind speed for different vehicle and as per its speed wind speed changes, making it was difficult to measure the wind speed. Additionally, we could record all voltage, RPM, and wind speed data electronically using a data logger. This would give us precise instantaneous measurements, which would allow us to calculate any lag between the RPM and wind speed values caused by vortices or fluctuation in wind speed. By having the wind speed data electronically saved, it would be possible to average the wind speed to accurately match the wind speed with the RPM of the turbine. Another improvement we would make is modifying the tower structure to reduce vibrations. The current tower design incorporates many reducers which makes the connection between the legs and main shaft weak.

According to theoretical calculations the main shaft should only have deflected 5.95 mm. However, video analysis shows that the turbine actually deflects 8.3 mm in 15 m/s wind speeds. This excess deflection reduced the turbine’s efficiency since a portion of the available wind energy is being lost to vibration. Improving the design can be done by redesigning the tower so that the main shaft is supported at two points instead of just one. Another method to increase the power output is to improve the power matching of the turbine and the generator. When we first matched the turbine and the generator, we did not take into account any vibrational and frictional losses. These losses resulted in a decrease in power produced by the turbine.

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