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Development of vertical axis wind turbine for Domestic application

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ABSTRACT

The most common application for the wind turbine variety known as the vertical axis wind turbine is to supply homes with green energy. The rotor shaft and one, two, or three blades are part of this turbine, and the rotor shaft travels vertically. Therefore, the spinning of coins on the edge is linked to the movement of the rotor. In this turbine, the generator is positioned at the foot of the structure whereas the blades are covered around the shaft. To position the rotor and catch airflow, they depend on the yaw system.Vertical axis wind turbines can produce electricity even in unsteady weather conditions like the turbulent, strong wind because of this distinct difference in operation mechanism. They work well in mountainous and seaside regions as well. Other than producing electricity, VAWT has a wide range of other uses. Wind power can be converted from its original form to kinetic energy and thermal energy. As a result, the VAWT energy system can also be used for other purposes, such as heating or ventilation.

Keywords:Wind turbine, Vertical axis, Domestic. Development.*

1. INTRODUCTION

Windmills are very important since they provide a way to produce, a way to produce electricity without causing pollution, which is a healthier option for our environment. The American windmill or wind engine was 1st invented by Daniel Halladay in 1854 & was used mostly for lifting water from wells. Wind power is also a renewable resource. This means that it will continue to be available on earth since wind is constantly produced. The difference between a windmill & Wind Turbine is that windmill is a device that converts wind power into rotational energy that comes from the wind, whereasa Wind turbine is a device that converts kinetic energy into electrical energy. A windmill is a machine that converts energy from the wind into usable energy through the rotation of a wheel made up & down of adjustable blades by lifting, especially water from the ground, to power machines that crush grain & process foods. Windmills are constructed on-site using hand tools.Wind energy is produced by converting the kinetic energy of atmospheric air into mechanical energy. The vertical axis wind turbine (VAWT) and horizontal axis wind turbine (HAWT) are the turbines used to convert mechanical energy from kinetic energy.

Saeidi*et al.* [1]studied the growing demand for renewable energy with a sustainable and low-energy design is the main topic in many countries. This could indeed influence the utilizationof small wind turbines which incorporate innovative designs and new materials of construction which may provide an attractive prospect for future applications of power production in the urban environment. In particular, H-rotor type vertical axis wind turbines (VAWTs) are considered one of the most attractive solutions due to their simplicity and ease of manufacturing. Optimized site-specific designs proved reductions in the cost of energy by increasing annual energy yield and a reduction in manufacturing costs. The greatest benefits were reported at sites with low mean wind speed and low turbulence. The terrain studied here is a site in the Fadashk area in the province of south Khorasan in the northeast of Iran. This work aims to design and optimize the site-specific H-rotor type VAWT using the blade element momentum theory (BEM) and a double multiple stream tube model. The results of these analyses were then combined and synthesized for a 1.5 kW H-rotor VAWT with NACA4415 airfoil sections. The economic feasibility of the designed VAWT is finally integrated into the design procedure to predict the annual production of electricity. Based on current electricity costs whichare 12 cents per kW h in Iran for renewable energies, our evaluation shows a profit of 6 cents per each kW h generated power by the designed VAWT. Kavade*et al.* [2]have found that VAWTs are suggested as a better choice for cities and isolated semi-urban areas. It was concluded that further research is critical in making VAWTs a viable, dependable, and affordable power generation technology for many low and decentralized power applications.Mahmud*et al.* [3] have wind energy as one of the non-conventional forms of energy and it is available in affluence. Electricity can be generated with the help of a vertical-axis wind turbine. This project aims of utilizing this wind energy most effectively to get the maximum electric output, and therefore we selected the highway as our installation site where we can take the advantage of the moving vehicles on both sides of the road. In the present work turbine is designed and fabricated as per the specifications, the blades used are semi-circular in shape and are connected to the disc which is connected to the shaft. The shaft is then coupled with the pulley with the help of a bearing, and then the pulley is connected to the alternator, which generates the power. The power developed is stored in the battery and then can be used for street lights, signals, or tolls. In this project, a small model has been created for testing purposes. This project also aims for maximum output with minimum cost indulges, so that the government can think over this project and can implement this type of vertical axis wind turbine on highways at low cost.Khudri Johari *et al.* [4]have researched renewable is seen as a next-generation source of energy for meeting rising energy demands and depleting fossil fuels. Solar, biomass, geothermal, hydroelectric, and wind are renewable and can produce huge megawatts of power. Among all these, the wind is the cheapest renewable source of energy. This fast-growing wind energy source needs to be utilized. Based on structure, wind turbines are broadly classified as Horizontal Axis Wind Turbine (HAWT) and Vertical Axis Wind Turbine (VAWT). VAWT can tap wind energy from any direction, while HAWT can tap wind from only one direction. But still, HAWT is being researched and used more as it taps more wind energy as compared to VAWT. Traditional HAWT has unreasonable efficiencies so the focus has slightly shifted to VAWT. Economically HAWT is better than VAWT but VAWT is more portable. This paper deals with the different classifications of turbines, the relative comparison between them, and the development of mathematical modeling of wind turbines. Howell *et al.* [5] have presented a combined experimental and computational study into the aerodynamics and performance of a small-scale vertical axis wind turbine (VAWT). Wind tunnel tests were carried out to ascertain the overall performance of the turbine and two- and three-dimensional unsteady computational fluid dynamics (CFD) models were generated to help understand the aerodynamics of this performance.Wind tunnel performance results are presented for cases of different wind velocities, tip-speed ratio, and solidity as well as rotor blade surface finish. It is shown experimentally that the surface roughness on the turbine rotor blades has a significant effect on performance. Below a critical wind speed (Reynolds number of 30,000) the performance of the turbine is degraded by a smooth rotor surface finish but above it, the turbine performance is enhanced by a smooth surface finish. Both two-bladed and three-bladed rotors were tested and a significant increase in performance coefficient is observed for the higher solidity rotors (three-bladed rotors) over most of the operating range. Dynamic stalling behaviour and the resulting large and rapid changes in force coefficients and the rotor torque are shown to be the likely cause of changes to the rotor pitch angle that occurred during early testing. This small change in pitch angle caused significant decreases in performance.The performance coefficient predicted by the two-dimensional computational model is significantly higher than that of the experimental and the three-dimensional CFD model. The predictions show that the presence of the over-tip vortices in the 3D simulations is responsible for producing a large difference in efficiency compared to the 2D predictions. The dynamic behavior of the over-tip vortex as a rotor blade rotates through each revolution is also explored in the paper. Aslam Bhutta*et al.* [6]studiedthe increasing concern for the environment which has led to the search for more environment-friendly sources of energy. Wind energy can be a viable option in this regard. Vertical-axis wind turbines offer a promising solution for areas away from the integrated grid systems. However, they have certain drawbacks associated with different configurations. This paper reviews various configurations of VAWT along with their merits and demerits. Moreover, design techniques employed for VAWT design have also been reviewed along with their results. It was learned that the coefficient of power (C_P) for various configurations is different and can be optimized concerning Tip Speed Ratio. The latest emerging design techniques can be helpful in this optimization. Furthermore, the flow field around the blade can also be investigated with the help of these design techniques for safe operation.Varun*et al.* [7] have noticed that Wind energy is one of the major forms of renewable energy resources found abundantly which is widely used as an alternative energy. Wind power is sustainable and the production of electricity using wind energy is increasing day by day due to the lack of availability of fossil fuels. The energy can be converted into electricity by using a vertical-axis wind turbine (VAWT) and a Horizontal axis wind turbine (HAWT). The vertical axis wind turbine is highly used for domestic applications where the volume of production is low and efficiency is optimal while the horizontal axis wind turbine is widely for a larger volume of production and requires huge investment and the efficiency is high. This paper focused on increasing the efficiency of using wind energy by producing a large amount of electricity and reducing the space for installation. This can be done by combining the vertical axis wind turbine (VAWT) and horizontal axis wind turbine (HAWT) in the same tower. The combined vertical and horizontal axis wind turbine reduces the cost for the larger volume of electricity generation.Ahmad*et al.* [8] As the demand for green technology is rising rapidly worldwide, Malaysian researchers must take advantage of Malaysia's windy climates and areas to initiate more power generation projects using wind. The main objectives of this study are to build a functional wind turbine and to compare the performance of two types of design for wind turbines under different speeds and behaviours of the wind. A three-blade horizontal axis wind turbine (HAWT) and a Darrieus-type vertical axis wind turbine (VAWT) have been designed with CATIA software and constructed using a 3D-printing method. Both wind turbines have undergone a series of tests before the voltage

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and current output from the wind turbines are collected. The result of the test is used to compare the performance of both wind turbines which will imply which design has the best efficiency and performance for Malaysia's tropical climate. While HAWT can generate a higher voltage (up to 8.99 V at one point), it decreases back to 0 V when the wind angle changes. VAWT, however, can generate a lower voltage (1.4 V) but changes in the wind angle do not affect its voltage output at all. The analysis has proven that VAWT is significantly more efficient to be built and utilized for Malaysia's tropical and windy climates. This is also an initiative project to gauge the possibility of building wind turbines, which could be built on the extensive and windy areas surrounding Malaysian airports. Shikha*et al.* [9]have briefly described that Wind energy is one of the most promising renewable energy resources for power generation, and rapid growth has been seen in its acceptance since 2000. The most acceptable classification for wind turbines is by their axis of orientation: Horizontal Axis Wind Turbines (HAWT) and Vertical Axis Wind Turbines (VAWT). HAWTs are used in many countries for medium-to-large scale power projects, and most commercial installations around the globe are solely based on these turbines. On the other hand, HAWTs are not recognized as a viable option to harness the energy of the wind in urban areas, where the wind is less intense, much more chaotic, and turbulent. VAWTis suggested as a better choice for cities and isolated semi-urban areas. Several attributes have been suggested for the large-scale deployment of VAWTs, e.g., good performance under weak and unstable wind, no noise and safety concerns, and aesthetically sound for integration in urban areas. Significant research has been published on wind turbine technology and resources assessment methodologies, and this review paper is a modest attempt to highlight some of the major developments of VAWTs, with a focus on the integration with urban infrastructure. Several recommendations have been drawn based on the state-of-the-art information on the subject for future studies and acceptance of wind turbines in urban areas. It was concluded that further research is critical in making VAWTs a viable, dependable, and affordable power generation technology for many low and decentralized power applications.Kumar*et al.* [10]current review is to present the development of a large vertical axis wind turbine (VAWT). The turbines are critically reviewed in terms of performance, blade configuration, tower design, and mode of failure. The early VAWTs mostly failed due to metal fatigue since the composites were not developed. Revisiting those configurations could yield insight into the future development of VAWT. The challenges faced by a horizontal axis wind turbine (HAWT), especially in the megawatt capacity, renewed interest in large-scale VAWT. VAWT provides a solution for some of the immediate challenges faced by HAWT in the offshore environment in terms of reliability, maintenance, and cost. The current rate of research and development on VAWT could lead to potential and economical alternatives for HAWT. The current summary on VAWT is envisioned to be an information hub about the growth of the Darrieus turbine from the kW capacity to the megawatt scale. Xie*et al.* [11]have designed the vertical axis wind turbines (VAWT), and the wake effect of the upstream VAWT on the downstream VAWT needs to be considered. To simulate the velocity distribution of a VAWT wake rapidly, a new two-dimensional numerical method is proposed, which can make the array design easier and faster. In this new approach, the finite vortex method and vortex particle method are combined to simulate the generation and evolution of the vortex, respectively, and the fast multipole method (FMM) is used to accelerate the calculation. Based on a characteristic of the VAWT wake, that is, the velocity distribution can be fitted into a power-law function, a new correction model is introduced to correct the three-dimensional effect of the VAWT wake. Finally, the simulation results can be approximated to the published experimental results in the firstorder. As a new numerical method to simulate the complex VAWT wake, this paper proves the feasibility of the method and makes a preliminary validation. This method is not used to simulate the complex three-dimensional turbulent evolution but to simulate the velocity distribution quickly and relatively accurately, which meets the requirement for rapid simulation in the preliminary array design. Dabachi*et al.* [12]have started work on the development of Floating Vertical Axis Wind Turbines, which have significant advantages over Floating Horizontal Axis Wind Turbines. In the present work, we expose a brief history of the use of this type of wind turbine, and we contribute to understanding the existing technologies we also propose a new design of a Floating H-Darrieus Vertical Axis Wind Turbine with three-stage rotors. This design solves the problem of starting a large turbine and facilitates maintenance by adopting three mechanisms Bearing Swivel Rollers at each stage. We use the Double Multiple StreamTube method for aerodynamic simulations. The numerical results of the aerodynamic performance analysis show that variable radius rotors maximize the power generated.Mohammed *et al.*[13] studied the blade pitch angle has a significant influence on the aerodynamic characteristics of horizontal axis wind turbines. However, few research results have revealed its impact on the straight-bladed vertical axis wind turbine (Sb-VAWT). In this paper, wind tunnel experiments and CFD simulations were performed at the Sb-VAWT to investigate the effect of different blade pitch angles on the pressure distribution on the blade surface, the torque coefficient, and the power coefficient. In this study, the airfoil type was NACA0021 with two blades. The Sb-VAWT had a rotor radius of 1.0 m with a spanwise length of 1.2 m. The simulations were based on the k-ω Shear Stress Transport (SST) turbulence model and the wind tunnel experiments were carried out using a high-speed multiport pressure device. As a result, it was found that the maximum pressure difference on the blade surface was obtained at the blade pitch angle of $\beta = 6^\circ$ in the upstream region. However, the maximum pressure coefficient was shown at the blade pitch angle of $\beta = 8^\circ$ in the downstream region. The torque coefficient acting on a single blade reached its maximum value at the blade pitch angle of $\beta = 6^\circ$. As the tip speed ratio increased, the power coefficient became higher and reached the optimum level. Subsequently, a further increase in the tip speed ratio only led to a quick reversion of the power coefficient. In addition, the results from CFD simulations had also a good agreement with the results from the wind tunnel experiments. As a result, the blade pitch angle did not have a significant influence on the aerodynamic characteristics of the Sb-VAWT.Siram*et al.* [14]have studied the Momentum models or streamtube models represent one of the fundamental approaches in modeling the aerodynamics of straight-bladed vertical axis wind turbine (SB-VAWT) of Darrieus type. They are based on momentum (actuator disk) theory and are widely used in the performance evaluation of VAWTs. In this short review, the authors have strived to compile the basic momentum models that have been widely assumed in the literature for the design and performance estimation of SB-VAWTs of the Darrieus type. A comprehensive demonstration of the formulation needed for the implantation of these models is also proposed. Three streamtube models are investigated in this paper, namely, the single streamtube (SST), the multiple streamtube (MST), and the double multiple streamtube (DMST) models. Each of these models has its merits and demerits which are also thoroughly discussed in this review.Damota*et al.* [15]have studied the small-scale horizontal-axis wind turbines (SHAWTs) that have emerged as a promising alternative energy resources for off-grid electrical power generation. These turbines primarily operate at low Reynolds numbers and low tip speed ratio conditions. Under such circumstances, the air foil selection and blade design of a SHAWT becomes a challenging task. The present work puts forward the necessary steps starting from the aerofoil selection to the blade design and analysis utilizing blade element momentum theory (BEMT) for the development of four model turbine rotors composed of E216, SG6043, NACA63415, and NACA0012 airfoils. This analysis shows the superior performance of the model rotor with the E216 airfoil in comparison with the other three models. However, in the subsequent wind tunnel study with the E216 model, a marginal drop in its performance due to mechanical losses has been observed.

1.1. OBJECTIVE OF THE STUDY

For the last decades as so, much researchhas been done by the researchers of many institutions and by the government itself. The objectives of the study are:

- To check whether the rapid climate change of the state due to pollution affected the windspeed of the northeast as well as Tripura.
- For the last few decades, it was nearly impossible to generate power or electricity by wind energy for domestic purposes.
- To check whether the present environment of the state as especially hilly areas like Jampui hills, Langarai, are capable or as the ability to drag the blades of the vertical axis wind turbine to generate minimal electricity for domestic purposes

2. MATERIALS AND METHODS

House of Quality (HOQ) helps in the planning process of designing the Giromill wind turbine by examining the customer satisfaction information. In HOQ, there have steps to begin which are clarifying customer needs, interrelationship matrix, engineering characteristics, technical correlation matrix, and target value/specification. To fulfill all the customer needs some of the factors should be considered in constructing a house of quality. Engineering characteristics identify what the customer requires and it must be achieved to satisfy these requirements. Then, the relationship between customer requirements and product requirements will be evaluated. Morphological chart generated the possible solution to design Giro mill wind turbine which helps to give the idea in the conceptual design section. The highest rank will be chosen among the five designs. For structure analysis, the pressure on the whole surface of the blade and the force applied on the edge of the blade is tested using simulation, and the result of displacement and von Mises stress is recorded. The value for pressure and force used is based on the wind speed stated in the previous section where the maximum wind speed is equal to 15.4 m/s. Moreover, the maximum pressure and force on the same location as stated above of the maximum allowable stress for the chosen material will be determined and compared with the result obtained from maximum wind speed. Lastly, topology optimization is carried out to generate the most optimal material distribution for the chosen design. Different from topography analysis, the chosen design can have optimal stress distribution throughout the blade as wind penetrates the blade and minimally used material in developing the prototype.

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3. WORKING PRINCIPLE

The device is similar way to a cup anemometer. The wind turbine working principle can be easily explained because this is considered the most streamlined turbine when compared with other turbines. This is a dragging kind of instrument where it consists of some 2 – 3 cups. From the above portion, when the rotor is seen, it appears in the shape of "S" in the form of a cross-section.Due to this curvature shape, the cups will have minimal dragging when they move in the opposite direction of the wind, whereas they experience maximum drag while moving in the same direction of the wind. This variation in the dragging creates the spinning movement of the turbine.

As these instruments are drag-type, they grab minimal wind power when compared with that of other same-sized lift kinds of turbines. Most of the brushed section of the rotor is close to the ground level when the device has minimal mount having no stretched post thus delivering low energy extraction because of the fewer wind speeds observed at lesser heights.The cups in the wind turbine will not have faster rotational speeds when compared with the wind speed and this creates a tip speed proportion of either one or less than one. This states that the device has minimal rotational speed but produces a higher amount of torque.So, these instruments are not exactly suitable for the production of electricity as they require higher RPMs for the generation of higher current and voltage values. For this, a gearbox can be inserted to minimize the torque and enhance the generator RPM level, and this corresponds that the turbine does not hold the ability to start by itself.Power output defines the higher power level which can be extricated from the airflow. Due to the mass and momentum conservation, there will be no complete energy extraction from the wind. With Betz's law, it was demonstrated that the higher amount of kinetic energy that was received from the wind should not go beyond 60%.So as per this principle, none of the turbines extracts the entire energy from the wind.This is the wind turbine working**.** The below picture is the curve that is plotted against the turbine's power coefficient to the ratio of before and after passage across the turbine. Betz's threshold is based on the wind turbine's horizontal axis and is not directly applicable to vertical kind of turbines.The curve which is plotted for power output shows the wind turbine's efficiency at various speed levels. The plot represents the power output of the wind speed and this provides a detailed thought regarding the lesser and higher levels of a wind turbine. The generated power is minimal than that of the received kinetic energy because it has to pass through a gearbox, and generator and these have lesser performances. Each turbine will have its specific required speed level to function. These devices will not operate at higher speed levels to obstruct mechanical damage.

Figure 1. Vertical axis wind turbine

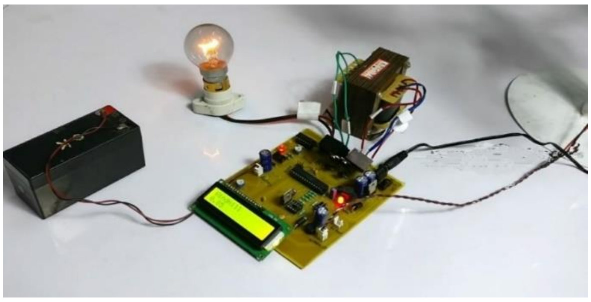

Figure 2. Circuit

4. DESIGN SPECIFICATION

The Specimens that are needed for doing our project more splendidly, are:-

i. DC Motor
ii. Connecting rod
iii. Vertical Blades
iv. LED Display
v. Multimeter
vi. Solder
vii. Multicutter
viii. Battery

Dimension

The dimensions of the vertical axis of the wind turbine which we are going to design are 50×30×45 centimeters.

5. CIRCUIT DESIGN

A circuit is any loop through which matter is carried. For an electronic circuit, the matter carried is the charge by electronics and the source of these electrons is the positive terminal of the voltage source. When this charge flows from the positive terminal, throughout the loop, and reaches the negative terminal, the circuit is said to be completed. However, this circuit consists of several components which affect the flow of charge in many ways. Some may provide a hindrance to the flow of charge, and some simply store or dissipate the charge. Some require an external source of energy and some supply energy. In this diagram, shown in Figure 3, it is described that power is to be supplied using a rectifier then it rectifies some data & circulates into an Atmega microcontroller (simply known as Embedded Pointer) through a regulator and then it again resends its speed by some source known as LED display and when blades move then a power gets generated and gets transferred by a charge controller and transferred to 12V battery to DC inverter then a source is to be added which is known to be as a step-up transformer which transforms some energy from primary side to secondary side and manages the same power at the rated frequency in both coils at a high voltage and low current and hence a MOSFET transistor which is used as a switch here is applied to get the load or output. A Block diagram is being used to represent the functions of H-motor straight blades with the wind turbine (VAWT) by using a circuit design shown in Figure 3.

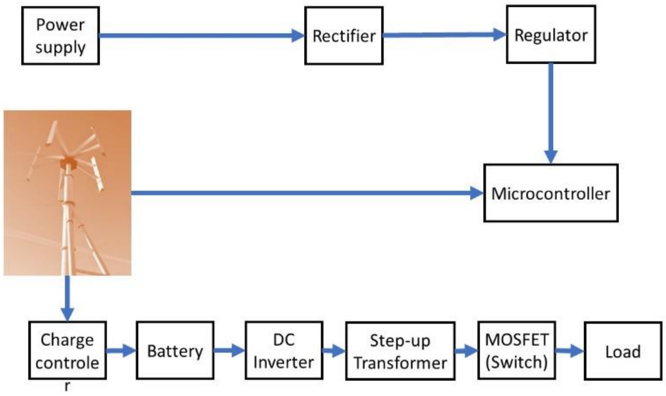

Figure 3. Block diagram of Vertical Axis Wind Turbine

6. ADVANTAGES

There are some advantages based on our design of “Vertical Axis Wind Turbine” are as follows:

- VAWTs are their capability to obtain wind from any direction.
- VAWTs do have a strong ability to resist wind compared with HAWTs
- VAWTs have much smaller noise than HAWTs as well.
- The potential capability of VAWTs to produce electricity at low wind speeds cannot be denied.
- Cheaper to produce than HAWTs
- More easily installed
- Easily Transport from one place to another.
- Can work in extreme weather with variable winds and even with mountain conditions.

7. DISADVANTAGES

There are some disadvantages based on our design of "Vertical Axis Wind Turbine" are as follows:

- Produce energy at only 50% of the efficiency of HAWTs.
- Installed on a relatively flat piece of land.
- Most VAWTs have low starting torque.
- Lower Wind speeds at ground level.
- Requires power and a starting motor to start the wind turbine
- Not as efficient as HAWTs.

8. APPLICATIONS

Various important applications are very much helpful in our daily life, these are;

- Used in Homes
- Used for domestic purposes
- Used in farmhouse
- Used in apartments
- Used in villas and resorts

9. CONCLUSION

Based on our design, we, therefore, conclude that the "Vertical Axis Wind Turbine" is efficient. We also conclude that the components that we used such as; D.C Motor, Mounts, connecting rod, Vertical Blades, supporting frames, screws and bolts, Joints and fixtures, etc are useful for rolling Wind Turbines. Though it takes several times before separate the pure wind from the polluted air, in the end, we will have been satisfied with the work of the Vertical Axis Wind Turbine. We can also say that the Vertical axis wind turbine (VAWT) is a creditable thing to own. Not just it is easy to make but what matters most is the commendable performance of this kind of vertical Wind turbine. Lastly, we conclude that Vertical axis wind turbine(VAWT) is not just only useful and economical, but it is also eco-friendly.

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