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REVIEW OF VERTICAL AXIS WIND TURBINE

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Abstract: - This paper involves study of Savonius Vertical Axis Wind Turbine (SVAWT) blades. In past few years more research works are carried out to increase efficiency of Vertical Axis Wind Turbine. Review of all these papers shows that the experiments are conducted only on semi cylindrical bucket shape blades, twisted blades, blades with end flap edges and blades having frames with cavity vanes, for two blades, three blades and four bladed Savonius Vertical Axis Wind Turbine(SVAWT) to increase performance. They also conducted experiments by providing curtains or flow guide to the rotor, increasing in the stages of rotor and combining both Savonius and Darrieus rotor (i.e. hybrid rotors) to increase the efficiency of rotor. ANSYS and Computational Fluid Dynamics are used for structural analysis and fluid flow performance of newly designed blade.

Keywords: Savonius Vertical Axis Wind Turbine, Flow guides, hybrid rotors, leading edge, CFD.

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INTRODUCTION

Change in climate is the biggest and most urgent environmental threat in the world. The greenhouse effect which is produced by human activity, by burning of fossil fuels such as coal, oil and gas for energy produced CO2, cause increases in global temperatures, leading to more severe weather patterns such as floods, droughts and storms, rising sea levels and threats to entire ecosystems. To avoid inconsistent environmental condition rising global emissions must decrease within the next 10 years. This means we need to adopt those forms of energy that do not produce CO2. With the recent deficiency in fossil fuels, demands for renewable energy sources are increasing, wind energy have become a most reliable technology for power generation. Currently, horizontal axis wind turbines (HAWT) dominate the wind energy market due to their large size and high power generation characteristics. However, vertical axis wind turbines (VAWT) are capable of producing a lot of power, and offer many advantages such as they are small, quiet, easy to install, can take wind from any direction, and operate efficiently in turbulent wind conditions, a new area in wind turbine research has opened up to meet the demands of individuals willing to take control and invest in small wind energy technology.

2.0. TYPES OF WIND TURBINES

Two major types of wind turbines exist based on their blade configuration and operation. The first type is the horizontal axis wind turbine (HAWT). HAWTs sit atop a large tower and have a set of blades that rotate about an axis parallel to the flow direction. These wind turbine blades operates similar to the rotary air craft. The second major type of wind turbine is the vertical axis wind turbine (VAWT). This type of wind turbine rotates about an axis that is perpendicular to the oncoming flow; hence, it can take wind from any direction. VAWTs consist of two major types, the Darrieus rotor and Savonius rotor. The Darrieus wind turbine is a VAWT that rotates around a central axis due to the lift produced by the rotating airfoils, whereas a Savonius rotor rotates due to the drag force created in blades. There is also a new type of VAWT emerging in the wind power industry which is a mixture between theDarrieus and Savonius designs.

Horizontal Axis Wind Turbines

The blades of a HAWT work to extract energy from the wind by generating lift, resulting in a net torque about the axis of rotation. To accomplish this task efficiently, especially for large HAWTs, active pitch controllers are used to ensure that each blade is adjusted to maintain an optimal angle of attack for maximum power extraction for a given wind speed. However, in HAWT contains more complex parts like control system and it require more moving parts and effort to install than a VAWT assembly where the only moving part is the rotor and the majority of components are located at the base of the turbine.

Vertical Axis Wind Turbines

Now days VAWTs have been gaining popularity due to interest in personal green energy solutions. Small companies all over the world have been marketing these new devices such as Helix Wind, Urban Green Energy, and Wind spire. VAWTs target individual homes, farms, or small residential areas as a way of providing local and personal wind energy. This produces an external energy resource and opens up a whole new market in alternative energy technology. Because VAWTs are small, quiet, easy to install, can take wind from any direction, and operate efficiently in turbulent wind conditions. VAWT is relatively simple its major moving component is the rotor and the more complex parts like the gearbox and generator are located at the base of the wind turbine. This makes installing a VAWT a painless undertaking and can be accomplished quickly. Manufacturing a VAWT is much simpler than a HAWT due to the constant cross section blades. Because of the VAWTs shows simple manufacturing process and installation, they are perfectly suited for residential applications. An S-VAWT generates electricity through drag force rather than lift force like the D-VAWT. As the wind hits the concave portion of the blade (the bucket), it becomes trapped and pushes the blade around, advancing the next bucket into position. This continues as long as the wind is blowing and can overcome the friction of the shaft about which the blades rotate. A Savonius rotor typically rotates with a velocity equivalent to the speed of the free stream velocity, or a tip speed ratio of one. Because of its lower rotation speed, Savonius rotors shows lower efficiencies and are not capable of providing adequate electricity, but it is used to reduce the overall dependence on other energy resources. However, due to the Savonius wind turbines simplicity, manufacturing is very easy; some have even been built using large plastic blue poly drums with the capability of providing up to 10% of a household's electricity In drag-based wind turbines, the force of the wind pushes against a surface, like an open sail. It works because the drag force of the open, or concave, face of the cylinder is greater than the drag force on the closed or convex section. Vertical axis wind turbines are classified in to two major types; Savonius turbine type and Darrieus turbine type.

Savonius typesbladedesign uses aerodynamic drag from wind to rotate the blades Andproduce power. Savonius type blades are rugged and simplistic. This can reduce costs since they are easier to manufacture, need less maintenance, and can last longer designs. An example of a Savonius blade type design is seen below in Figure-1.1.

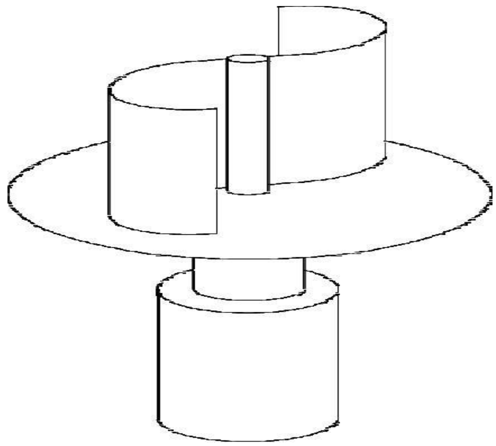

Figure-1.1 Savonius blade design

Darrieus Turbine Type can spin faster than the speed of the wind, which results in a higher efficiency. However, this higher efficiency comes with a great cost. The blade is harder to manufacture than a Savonius blade, increasing the cost of production. Also, normal Darrieus type VAWTs are not self-starting, and thus needs to have a motor or other solution to bring it up to a sufficient speed where it can start producing its own energy.

3.0. LITERATURE SURVEY

VAWTs consist of two major types, the Darrieus rotor and Savonius rotor. The Darrieus wind turbine is a VAWT that rotates around a central axis due to the lift force produced by the rotating airfoils, whereas a Savonius rotor rotates due to the drag force created by its blades. To increase the efficiency of the wind turbine the designing of blade plays an very important role, according to literature there are many experiments were conducted on design and analysis of Savonius VAWT blade, the following are some of the literature reviews on design and analysis of Savonius VAWT blades, they conducted many experiments and analysis has been carried out for different overlap ratio, blades having with end plate or without end plate, for different wind speed, different tip speed ratio, different Reynolds numbers, coefficient of power (Cp). The following are some of the literature reviews on Savonius Vertical Axis Wind Turbine blades:

A.A. Kadam, et al. [1];

Has studied about Savonius wind rotors and identify the various performance parameters to increase its efficiency. The experimental results show that three blades rotor is more stable in operation than two rotor blades, the power coefficient increases with increasing the aspect ratio. The rotor blades with end plates gave higher efficiency than those of without end plates. CFD analysis was carried out to study the flow behavior of a rotating three bucket Savonius rotor. Model the complex flow physics around the rotating rotor was carried out by Fluent 6.3.26 software. For this purpose, data were taken from the experiments conducted earlier on the rotor in a subsonic wind tunnel for five different overlap conditions are 16.2%, 20%, 25%, 30% & 35%.and results shows that the maximum pressure drop is found in case of 16.2% overlap and minimum in case of 35% overlap, means that at 16.2% overlap condition power extraction is maximum from the wind.

Mohammed Hadiet al. [2];

Has carried out experimental comparison and investigation of performance between two and three blades Savonius wind turbine. Due to this purpose, two models of two and three semi-cylindrical blades were designed and fabricated from Aluminum 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 under low 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 savonius wind turbine.

N.H. Mahmoud, et al. [3];

Has conducted an experimental analysis by using, wind tunnel experimental setup, the experimental results shows that -Three bladed Savonius rotors are more efficient than the three and four bladed Savonius rotors. The rotor with end plates gives higher efficiency than the without end plates. Blades having overlap ratios are better than the blades with without over lap ratios. By increasing Aspect Ratio Coefficient of performance (Cp) will also increase.

Ivan Dobrev, et al. [4];

Has studied about flow through savonius vertical axis wind turbine type with aspect ratio having equal to almost 1. They studied simulation with both two dimensional and three dimensional models.CFD analysis was carried out to find the behavior of savonius wind turbine under flow field condition and performance evaluation , the flow analysis helps in determining the design was stable or not. The simulation was validated by the experimental investigation in wind tunnel carried out with PIV(Particle image velocimetry) with rotor azimuthal position.PIV was used to measure the instantaneous velocity field in the middle of the rotor normally to the axis of rotation.

K.K. Matrawy, et al. [5];

Has considered main design and performance parameters of a small scale vertical axis wind turbine (VAWT). They design two models (Two and Four cambered blades) and tested in an open wind tunnel. The studied parameters including: variation of rotational speed at different blade angles as well as variation of torque and power coefficients at different tip-speed ratios. They also carried out to investigation on the performance of (VAWT) with/without leading edge flap blades. The experimental data obtained at different blade angles for different ranges are noted down and analyzed in order to give an optimal blade angle through the study. A simple theoretical model is developed to verify and check up some experimental results. The final experimental results showed that the blade angle of 45^o increase the performance of (VAWT) comparing the other ones for both two and four bladedrotors. Using of flap blade which shows increase power coefficient by 2.4% compared with the same model without flap blade.

Patel C.R, et al. [6];

Has investigated the aerodynamic performance of Savonius wind turbine. Wind tunnel was used to find the aerodynamic characteristics like, drag coefficient, torque coefficient, and power coefficient of three bladed Savonius wind turbine rotor models, with and without overlap ratio, at various Reynolds numbers. Numerical investigation was also carried out to find those aerodynamic characteristics. Commercial computational fluid dynamic (CFD) software GAMBIT and FLUENT were used for numerical investigation. Three different models with different overlap ratio were designed and fabricated for the current study to find the effect of overlap ratios. At higher Reynolds number, turbine Model without overlap ratio gives better aerodynamic coefficients and at lower Reynolds number Model with moderate overlap ratio gives better results.

K.K. Sharma, et al. [7];

Has studied about the performance of a two-stage two-bladed configuration of the Savonius rotor. Experiments were conducted in a subsonic wind tunnel. The parameters studied are overlap, tip speed ratio, power coefficient (Cp) and torque coefficient (Ct). Optimized Overlap ratio was used to generate maximum performance of the rotor. The study showed that a maximum Cp of 0.517 was obtained at 9.37% overlap condition. Similarly power and torque coefficients decrease with the increase of overlap from 9.37% to 19.87%.

Ahmed Y., et al. [8];

Has designed vertical axis wind turbine model having three frames with cavity vanes, fabricated and tested in a low speed wind tunnel. This type of model has a high drag coefficient when the vanes close the frame on one side while rotating with wind direction and capture the wind efficiently. On the other side, the frame rotates in the opposite direction of the wind which opens the frame causing the wind to pass through the frame with low resistance. The model is tested in a wind tunnel with the different wind speeds. This new model gives the maximum power coefficient of 0.32 at a wind speed of 8.2 m/s and tip speed ratio of 0.31.

BurcinDedaAltan, et al. [9];

Has introduced a new curtaining arrangement to improve the performance of Savonius wind rotors. The curtain arrangement was placed in front of the rotor to avoid negative torque opposite the rotor rotation. The geometrical parameters were designed to increase the performance. The rotor with different curtain arrangements were tested out of a wind tunnel and its performance was compared with that of the conventional rotor. The maximum power coefficient of the Savonius wind rotor is increased to about 38.5% with the optimum curtain arrangement. The experimental results showed that the performance of Savonius wind rotors could be improved with a suitable curtain arrangement.

R. D. Maldonado, et al. [10];

Has done detailed investigation on Savonius wind rotor in order to obtain the optimal characteristics. They designed Savonius wind rotor assembly with CAD software. Simulations of the interaction between the flow of air and blades were developed through finite element analysis (FEA). A result of these simulations shows the velocity distribution of the profile blades. The formations of vortices were studied with the finality to improve the performance of the Savonius rotor. Blades with different geometry and gap distance between the blades were simulated, the results shown better geometry for the blade and gap distance between blades that improved the power coefficient (Cp) of the Savonius rotor. Simulations results show that the geometry and gap distance of the blades increases the Cp about 20%. Through gap distance between the blades, the wind was directed to the surface of following blade to induce its rotation. An air deflector was located front the Savonius rotor to increase and guide the flow of air to the blades. The deflector increased the velocity of the Savonius rotor up to 32%.

AnimeshGhosh, et al. [11];

Has studied about design and performance of Savonius, H-Darrieus and combined Savonius-Darrieus turbines. The experiments were conducted for Savonius rotor for different overlap ratios from 16.2% to 35%. Results show that optimum value of overlap is 20% at which the maximum Coefficient of performance (Cp) is 0.38, for a Tip Speed Ratio 0.625. Wind tunnel experiments were conducted for two bladed and three bladed H-Darrieus turbine to find the performances. Results show that both the turbines produced a similar value of maximum aerodynamic torque and two bladed H-Darrieus turbine shows higher coefficient of performance than the three bladed turbines. They also did comparative study on a three bucket Savonius turbine & a combined three-bucket Savonius and three-bladed Darrieus turbines with and without overlap ratios with different Tip Speed Ratio. The maximum Cp of 0.51 was obtained without the overlap condition. The performance of the combined Darrieus-Savonius turbine both theoretically and experimentally holds good. It was found that the combined Savonius-Darrieus turbine was the best of all the turbines reviewed in terms of power coefficient. Thus, the combined Savonius-Darrieus turbine may be used for small-scale applications by scaling-up the turbine.

K.K. Sharma, et al. [12];

Has studied about the Combination of Savonius and Darrieus type of Vertical Axis Wind Turbine (VAWT) rotors, which possess many advantages over their individual designs, like low starting torque, high power coefficient, low cut-in wind speed etc. They measured the performance of a three-bladed combined Darrieus-Savonius rotor, with Darrieus mounted on top of Savonius rotor, for overlap variations from 10.8% to 25.8%. Power coefficients (Cp) and torque coefficients (Ct) were calculated in a low range of Tip Speed Ratio for each overlap condition. It is found that Cp increases with the increase of overlap. However, there is an optimum value of overlap for which, Cp is maximum, beyond this Cp starts decreasing. The similar trend is observed for Ct as well. The maximum Cp of 0.53 is obtained at 0.604 Tip Speed Ratio (TSR) for an optimum 16.8% overlap ratio. The performance of the rotor is also compared with another version of this hybrid design with Savonius mounted on top of Darrieus rotor. The present Darrieus-Savonius rotor can be suitably placed in the built environment where it can harness more power from wind and, at the same time, would self-start in low wind condition prevalent in such environment.

4.0. CONCLUSIONS

The reviews show that there is lot of research work is going on Vertical Axis Wind Turbine to increase performance. Computational Fluid Dynamics is used to analysis the flow behavior of the rotor in both 2-Dimensional and 3-Dimensional.The experimental work shows that

1. Three bladed Savonius rotor is more efficient than the two bladed Savonius rotor.

2. The rotor with end plate shows more performance than the rotor without a end plate.

3. Rotor with Overlap have higher performance than without over lap ratio.

4. By increasing stages of rotor, shows the increase in coefficient of performance.

5. The research work is going on hybrid wind turbine to equate the performance with the Horizontal Axis Wind Turbine.

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