A Review of Vertical Axis Wind Turbine Structures

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ABSTRACT- *Renewable energy in the form of wind power is considered as more economical than other conventional energy. Sources such as oil and coal. The wind turbines are broadly classified as Horizontal Axis Wind Turbine (HAWT) and Vertical Axis Wind Turbine (VAWT).The Horizontal Axis Wind Turbine (HAWT) are more efficient and generate more power than Vertical Axis Wind Turbine (VAWT) at high wind speed. Alternately Vertical Wind Turbine (VAWT) are suitable for low wind speed, small power generation irrespective of low efficiency. The aim of this research paper is to summarize efforts taken by various researchers in the design of different types of innovative Vertical Axis Wind Turbine (VAWT) rotors which are improving turbines power performance.*

Index Terms- CFD, Numerical, Power, Speed, Wind

I. INTRODUCTION

VAWT has two main types vizSavonius and Darrius or H- rotor. Savonius rotor is simple in construction and shape of blade is semicircular whereas Darrius turbine consists of series of airfoils arranged at different angular positions. In VAWT generator is located near to the ground which results in less noise at low wind speed is considered as major advantage in power generation. Aerodynamic analysis of these rotors will give insight about the performance of wind turbine. In urban city VWAT are more suitable as wind speed is variable with advantages such as low starting torque, simple design and low cost. The design of VAWT focuses on various parameters like, blade shape, number of blades, aspect ratio, tip speed ratio, overlap ratio & solidity which are directly affecting the wind turbine power performance. If VAWT has low tip speed ratio which results in low noise. The aerodynamic loadings are accurately estimated by Blade Element Momentum Theory (BEM) and Computational Fluid Dynamics (CFD). The CFD analysis is costly as it requires more time.The accuracy of CFD analysis largely depends upon the selection of the meshing accuracy, physical model and turbulence model. A approach uses CFD for creating aerodynamic Coefficients at different angles of attack and Reynolds numbers. Then 3 D flow field is modeled via BEM method. Then, the applied torque and forces on turbine blades can be calculated. In this paper, review is taken about different types of VAWT regarding its constructional details which will help to understand power performance of turbine.

II. LITERATURE REVIEW

J. Kumbernuss et al.[1] has studied effect of Overlap ratio and phase shift angle in 2 stage 3 bladed wind turbine.The Overlap ratio should be moderate which affects wind turbines performance.

As Performance of wind turbine also depends upon velocity and highly affected by phase shift angle.HuiminWanga et al.[2] has investigated Variable Wind speed Turbulence modeling using CFD.2D numerical simulation of VAWT for different wind speeds is performed. The Rotational speed has significant effect on wake structures kinetic energy in rotation and calculation domain of numerical simulations.N.H. Mahmoud et al. [3] studied different models of Savonius rotor with varying Overlap ratio& aspect ratio. The Experimental result shows that the rotor without overlap ratio are good than rotor with overlap ratio. The Power coefficient increases with aspect ratio. Two blade rotor is good than three and four bladed rotor. TheRotor with end plate is good than without end plate.B. Yang et al. [4] investigated hydrofoil for helical VAWT using genetic algorithm for optimization.During study fitness function is obtained & modified lift to drag ratio. High power output after optimization due to stabilizing effect of concave shape of hydrofoil.K. McLaren et al. [5] studied Airfoils of a high solidity, H-type VAWT aerodynamic load with wind tunnel testing.Results shows the Strong dynamic excitation at support shaft and reduced by vibration isolations. Aerodynamic loads obtained for different blade speed ratios.Fang Feng et al. [6] Effect of icing on the performance of SBVAWT surface.Static blade for angle of attack icing occurs & icing amount is different for different angle of attack. Static torque reduces with iced blade. Dynamic torque is not greatly reduced by icing.S. McTavish et al. [7] studied Performance analysis of novel vertical axis wind Turbine with RANS CFD simulations, along with Steady and rotating validation studies.Results into comparable amount of static torque than conventional Savonius rotors. Dynamic torque generated reduces more rapidly with increasing tip speed ratio than conventional Savoniusrotors Torque reduces due to stagnation effects acting on the convex side of the outer wall as the blade is retreating. Shape of the inner and outer rotor walls need to be refined.Y.-F. Wang et al. [8] performed 3D CFD simulation Lotus shape micro VAWT Reducing the rotor inertia and deflecting wind flow. Accepts wind from all directions. Turbine has static blades (guide blades) and rotor blades (semicircular blades). Performance analysis of semicircular blades is done with semi-cylindrical or helically twisted blades and resulted that performance of semicircular blades is closed to semi cylindrical and slightly lower than helically twisted blades. During this study impact of guide blades is neglected.PlacideJaohindy et al. [9] Performed transient force analysis of a Savonius VAWT by CFD with varying aspect ratio.Comparison of Resultant force generated by Rotor A& Rotor B is done. Resultant force angle calculated reduces with increase in tip speed ratio. Longitudinal drag and lateral lift coefficients depends on the azimuth angle and the tip speed ratio of the rotor.

Lateral coefficient & longitudinal coefficient has a similar magnitude at low tip speed ratios and reduce after the peak power condition of the rotor.

M. SaqibHameed et al. [10] investigated Design parameters like Blade solidity, aspect ratio, pressure coefficient for the1kWpower output. Distortion in the shape of the blade must be considered while reducing the weight and centrifugal forces acting in the blade to achieve the best optimized cross section design.M.H. Nasef et al. [11] Evaluation of different overlap ratios with various turbulence model. Savonius rotor performance is studied with four turbulence models namely Standard k–ε, RNG k–ε, Realizable k–ε and SST k–ω. SST k–ω turbulence model is suitable for simulating the flow pattern around than other models for both stationary and rotating cases.
Reynolds Number and diameter have small effect on the static torque. Overlap increases pressure coefficient on the Concave return blade hence rotor performance is improved. Tong Zhou et al. [12] flow field and performance of Savonius rotors using numerical analysis. Bach-type rotor has better performance than conventional Savonius-type rotor. Gap and blade arc angle affects the performance VAWT. Instead of Semicircular shape length of straight portion of the blade and different shape of arc blade need to be studied.AtifShahzad et al. [13] Numerical simulation for varying wind speed of VAWT. VAWT behavior is different under transient conditions as compared to steady state input parameters. The blade positions corresponding to production of maximum and minimum torque output change during transient inlet velocity with respect to the normal condition.BavinLoganathan et al. [14] an experimental study of a cyclonic vertical axis wind turbine with cowling device is performed.The cowling device can be used to increase the power output of this cyclonic type VAWT especially with a reduce number of blades.Frederikus Wenehenubun et al. [15] Performance of Savonius rotor with number of blades. Number of blades will influence the rotation of rotor of wind turbine model. The four blades rotor has high torque compared with two or three blades and at lower tip speed ratio 4 blade has low performance. The three blade rotor has high performance at high tip speed ratio.NatapolKorprasertsak et al. [16] Investigated analysis of effect of wind boosters on power generation in VAWT. Wind booster improves performances of the VAWT at low speed wind conditions. The wind booster increases angular speed of a VAW which in turn increase in mechanical power generated from a VAWT. M. Elkhoury et al. [17] Performance of micro vertical-axis wind turbine (VAWT) with variable pitch is evaluated. The sliding mesh technique was used in the modeling of the variable-pitch mechanism.Thicker airfoils Tend to perform better for the considered fixed-pitch VAWT with High solidity ratio.SathitPongduang et al. [18] Helical Tidal Turbine Characteristics with Different Twists are evaluated. Helical angle has influence on turbine efficiency, while the turbine solidity had effect only on Tip Speed ratio (TSR). M.S. Hameed et al. [19] Finite Element Analysis of a Composite VAWT Blade resulting into study of bending stresses and deflection of blades. The effect of centrifugal forces acting on the blade can be further reduced by using the Glass-Epoxy instead of Aluminum. This is because Glass/Epoxy has a lower value of density as compared to Aluminum and a high strength to weight ratio. Ply orientation in composite material is important part for high strength of blade.Young-Tae Lee et al. [20] Performanceanalysis of a Darrieus-type (VAWT) with (NACA) airfoil blades.Model with high solidity produces a low power coefficient because it is affected by a stronger drag force. Optimum pitch angle is predicted to change in accordance with the angle of attack. Blade without helical angle has better power Performance.Du Gang et al. [21] Influences of installation angle and solidity of the performance of the VAWT. Unsteady Simulation under the RNG κ-ε turbulence model with sliding mesh is suitable for simulating the aerodynamic of the wind turbine. Wind turbine has a strong unsteady characteristic under working condition, the unsteady flow of the starting torque need to be considered.MojtabaTahani et al. [22] Optimization of straight blade VAWT with novel heuristic method. Method was a combination of a continuous/discrete optimization algorithm with double multiple stream tube (DMST) theory code. Average of vorticity magnitude around the optimized blade is larger than original blade and this results greater momentum and power coefficient.Abdullah Mobin Chowdhury et al. [23] Characteristics of VAWT in tilted and upright positions is studied. CFD simulation is better than BEM in predicting aerodynamic characteristics. VAWT in tilted condition produces greater torque at downwind in comparison to upright one.Qing'an Li et al. [24] Effect of solidity on aerodynamic forces in wind tunnel testing is done. Maximum values of lift and drag coefficients decrease with the increase of solidity for single blade. Fluctuations of lift-to-drag ratio changed slightly for different solidities and Reynolds numbers Re. The power coefficients decrease with the increase of the solidity vice versa.

Jae-Hoon Lee et al. [25] Performance and shape characteristics of a helical Savonius wind turbine at various helical angles. The simulation results successfully verified the experiment results at a range of TSRs and maximum power coefficient (Cp,max) values as the Savonius wind turbine blade twist angle was varied.

Torque coefficient varies with the azimuth and twist angles.David WafulaWekesa et al. [26] Numerical study of turbulence effect on Aerodynamic performance. Power production by wedge- generated turbulent flow was slightly higher than thatProduced by uniform flow. Self-starting capability of VAWT improved with external turbulent in flow. Turbulent inflow increases turbine power, but to withstand turbulent inflow turbine blade must have high strength.OkeogheneEboibi et al. [27] The higher solidity VAWT attained better overall Cp than the lower solidity VAWT due to differences in the flow field aerodynamics around the VAWT blades. Appropriate VAWT solidity gives better power performance.Min-Hsiung Yang et al. [28] Performance analysis of Innovative VAWT with deflectable blades. Comparing with the traditional vertical axis turbine FBT, the maximal power coefficient of DBT is much higher than that of FBT at low wind speed.A.R. Sengupta et al. [29] High solidity symmetrical and unsymmetrical blade H-Darrieus rotors are studied. High solidity unsymmetrical S815 blade H-Darrieus rotor possess higher static and dynamic torque coefficient and higher power coefficient than the symmetrical NACA 0018 and unsymmetrical EN0005 blade H-Darrieus rotors. High solidity cambered blade rotors need to be studied to improve power for low wind speed conditions.G. Ferrari et al. [30] Numerical analysis of a collapsible VAWT. The blades of the wind turbine were manufactured from composite materials. Design is having self-starting capability. Low cost & portable.AbdolrahimRezaeiha et al. [31] Effect of pitch angle on power performance of VAWT. Optimum fixed pitch angle can improve the performance of VAWT by more than 5% compared to zero pitch.

Introducing a fixed pitch to the blade is practically very simple and inexpensive. Optimum pitch angles for other tip speed ratios need to be studied.BavinLoganathan et al. [32] Effect of sizing of a multi-bladedSavonius rotor on power output is investigated.

Average power increased by 80% when comparing the base model with scaled up models (double sized). It was found that The models are scalable. As the dimensions of the blade and the rotor are doubled the area of the blades and the rotor also increased by double the size, however, the power output does not increase proportionally.Craig Stout et al. [33] Efficiency Improvement of VAWT with Upstream Deflector. Using small, curved upstream deflectors were found to improve the performance of turbine. Variations in the wind speed has resulted in variation of numerical & experimental models.Abdullah Al-Faruk et al. [34] Torque as well as power of the SST varies largely depends on the azimuth angle of the rotor, and performance is better at 0° and 45° positions compared to 90° and 135°. BavinLoganathan et al. [35] Feasibility of high aspect ratio of VAWT. The cut out semi elliptic shape offers a promising TF/RF ratio as the drag force generated from the curve at rear side of the semi elliptic is much lower than those of sharp edge from triangle cross section. The best aspect ratio is 2 which offers TF/RF ratio of 4.34 for cut out semi elliptic shape.

III. CONCLUSION

In this paper thirty five research papers on VAWT are reviewed.

All the authors have contributed about various aspects of VAWT including constructional details such as tip speed ratio, aspect ratio, overlap ratio, torque and power output either with numerical simulations or experimental analysis. The results summarized by each author has addressed about design and performance improvement of VAWT rotors. It is equally important to know effect of vibrations on the performance of VAWT rotor. The study suggests that it is important to continue future research work about the vibration analysis of VAWT by using simulation techniques and validating simulation results with experimental analysis.

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