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CFD Simulation on Vertical Axis Wind Turbine – A Review

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Abstract:-A wind turbine is a rotary device that absorbs energy from the wind. Wind energy is one of the most viable sources of renewable energy. Rotor blade is the main element in a wind turbine generator system to convert wind energy in to mechanical energy. Most blades available for commercial grade wind turbines incorporate airfoil shaped cross sections. These blades are found to be very efficient at lower wind speeds.CFD is a branch of fluid mechanics that uses numerical methods and algorithms to solve fluid flows problems. The study of VAWT aims at fulfilling this gap by developing turbines with the ranges between 300W to 500W. This characteristic has advantage of wind in the regions where it has low speed and high turbulence. CFD is used to simulate various airflows and directions and to analyze the effectiveness of VAWT. This paper reviews various configurations of VAWT along with their merits and demerits.

I. INTRODUCTION

In vertical axis wind turbines, vertical blades are attached to a vertical drive shaft which is effectively coupled to a generator and with electrical equipment. These generator and electrical equipment usually being located on the ground near the wind turbine.

VAWT'S turbine are categorized as

- Darrieus turbine
- Savonius turbine

VAWT are less expensive than horizontal axis wind turbine for a given power output. The blades of the vertical axis turbine are of a uniform cross-section from end- to-end are not tapered and not twisted when compared to HAWT. The vertical axis wind turbine blades are less expensive so that they can be made much lighter and can be supported at both ends. The entire length of the blades of the vertical axis wind turbine move at the maximum and uniform velocity through the air and each blade crosses the wind path twice per revolution thus the blades of VAWT will generate more power than HAWT. The tower of a VAWT is less expensive than the horizontal axis wind turbine tower. The blades of a vertical axis turbine are not close to the tower. The tower of a vertical axis wind turbine is not subject to a bending moment due to the gyroscopic reaction of turning a rotating mass for a changing wind direction. The tower does not have to support the weight of complex and heavy generation equipment at the upper end so the VAWT is less cost than HAWT. The VAWT tower does not require any nacelle support or yaw drive. In a vertical axis wind turbine, the generator and electrical equipment is located at ground level and the diameter of the generator is not moderated. The use of a large diameter slow-speed generator will eliminate the need for speed increased gearing. In VAWT the main rotor shaft is set.

vertically. Changes in wind direction have few negative effects because it needs not to be positioned according to wind direction.

II. NOMENCLATURE

C_p - Coefficient of power
N - Number of blades
B - Blade thickness
D - Rotor diameter
XYZ - subscript for stationary axes
xyz - subscript for rotating axes
M – Torque
$V\infty$ - free stream velocity
a,b – constants
c - scaling factor (dimensionless)
Wo - work rate
E – Power
A - cross-sectional area
Ψ – exergy energy
E_{xf} - wind flow energy
Exp - physical energy
$_{Exk}$ - kinematic energy
$\dot{m}$ - mass flow rate
C - specific heat coefficient
T - Temperature
R - general gas constant
P – pressure
Ft – thrust force
d – axial interference factor
F – Prandtl's tip loss correction
Fg – Gluert correction
Fd – turbine drag force
Fl – turbine lift force
V – Wind velocity
Vo – undisturbed wind wind velocity
$_{Va}$ – induced velocity
Vw – wake velocity
τ - Stress induced

K – Kinematic velocity
U – Velocity on boundary layer
Ha – angular momentum
I - inertia of the blade
ω - Angular velocity
Ω - operational frequency
ϱ - fluid density
λ – tip speed ratio
σ– constant = 0.28
Ƞ - efficiency

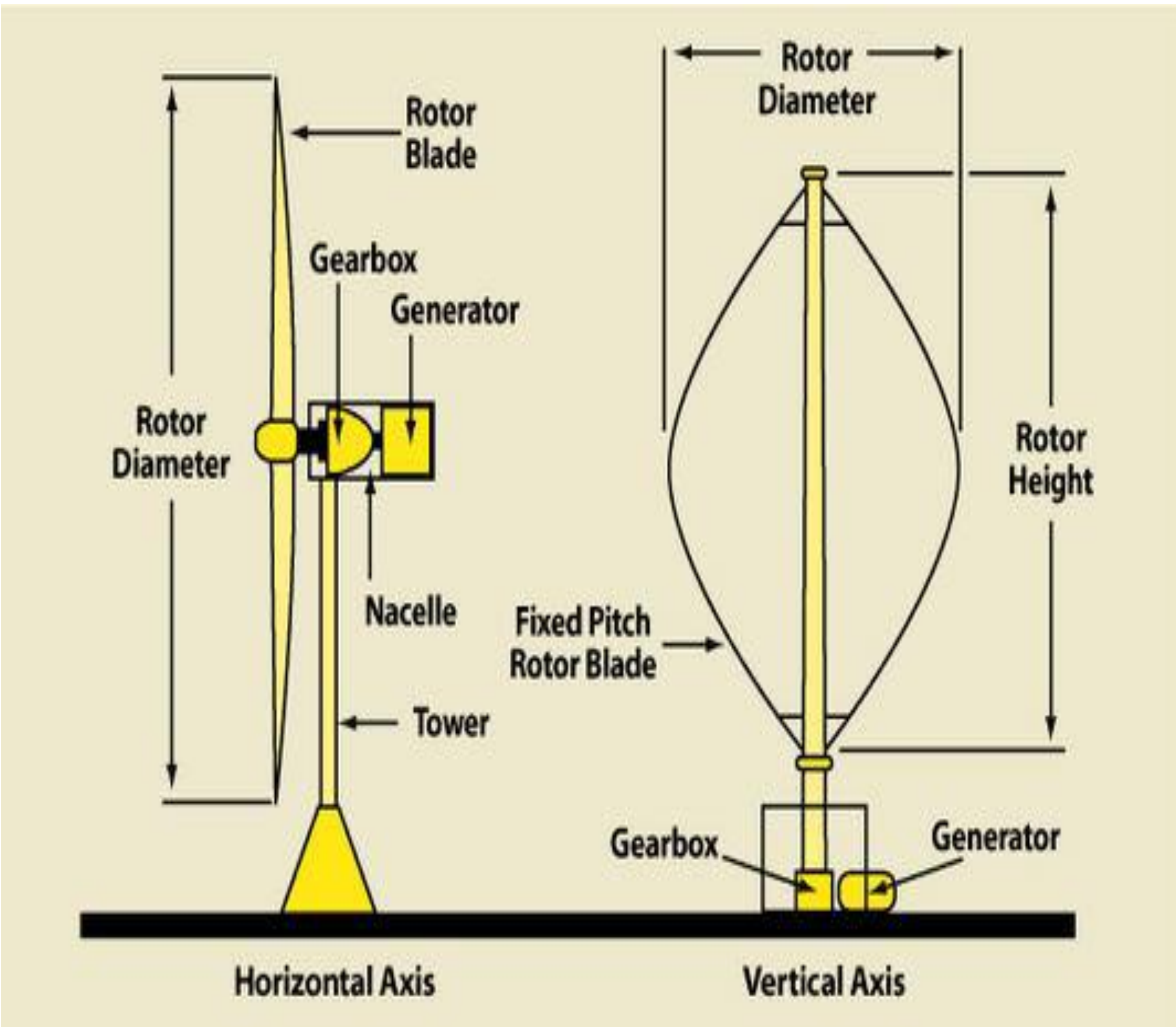

Fig 1. Horizontal and Vertical Axis Wind Turbine

III. LITERATURE REVIEW

S.NO	TITLE OF THE PAPER	AUTHOR	NAME OF THE JOURNALS	REMARKS
1.	CFD based synergistic analysis of wind turbines for roof mounted integration [1]	P.Larin , M.Paraschivoiu, C.Aygun	Journal of Wind Engineering and Industrial Aerodynamics	This realization led to investigating cup type turbines and the analysis showed promising results for six and seven bladed turbines with 30° circumferential cuts on the front and back of the blade. The blade number investigation showed that six and seven bladed turbines perform the best. The circumferential blade length study showed that as the blades were cut, the power coefficient increased and the peak power coefficient shifted to a higher TSR. The seven bladed turbine with double cut blades led to a power coefficient of 0.24, which represents a significant improvement relative bladed turbine placed in free stream with a power coefficient of 0.043for the conventionalblades,and0.0246forthedoublecut blades. A respectable power coefficient was achieved turbine on a 30.48m high building but future investigation for different building heights should be performed.
2.	Comparison of low-order aerodynamic models and RANS CFD for fullscale 3D vertical axis wind turbines [3]	P.L. Delafin, T. Nishino, A. Kolios, L.Wang	Renewable Energy	The results show that the three methods give very similar results and agree well with the experimental data for the turbine operating at its optimal (medium) tip speed ratio. A separate CFD analysis of a pitching airfoil carried out in this study suggested that the CFD results at the low tip speed ratio could be closer to the experiments if the mesh was refined. The results presented in this paper show that DMST models should be used carefully since they can fail to predict the optimal tip speed ratio and can also overestimate or underestimate turbine torque and thrust forces depending on the operating condition.
3.	Analysis and optimal design of wind boosters for Vertical Axis Wind Turbines at low wind speed [4]	Natapol Korprasertsak, Thananchai Leephakpreeda	Journal of Wind Engineering and Industrial Aerodynamics	A specially-designed wind booster is able to improve mechanical performance of the VAWT at low speed wind conditions. It can be observed in CFD analysis that the VAWT can rotate faster when it is equipped with a wind booster. Also, it can produce higher mechanical power. With optimization, the optimal design of a wind booster is found. The VAWT with an optimal wind booster is capable of producing mechanical power that is even higher than the original one. The CFD model is confirmed by very good agreement with experimental results of the optimal wind booster under real wind conditions at low speed.

4.	Influence of fluctuating wind conditions on vertical axis wind turbine using a three dimensional CFD model [5]	M.M.S.R.S. Bhargav, Velamati Ratna Kishore, Vaitla Laxman	Journal of Wind Engineering and Industrial Aerodynamics	Three dimensional RANS based CFD model is employed to study the performance of Darrieus VAWT subjected to fluctuating wind conditions. The effect of λ, Uamp and fc are evaluated in this study. The reference case is considered for Uamp=30%, fc=1 Hz and λmean=2 where cycle averaged fluctuating wind CP is 0.3 and uniform flow CP is 0.34. From the performance study, it is observed that the uniform and fluctuating wind CP curves do not trace each other. The effect of fluctuation amplitude (Uamp) is studied by running simulations at Uamp=10%, 20%, 30%, 40% and 50%. It is observed that as Uamp increases from 10% to 50%, cycle averaged CP continuously increased 0.284 to 0.329. The effect of fluctuation frequency is studied by running the simulation at fc=0.5 Hz, 0.75 Hz, 1 Hz, 1.5 Hz and 2 Hz. For fc < 1 Hz, increase in fc improves cycle averaged CP. However for fc > 1 Hz, increase in fc results in marginal decrease in CP. Maximum cycle averaged CP peak of 0.31 is observed at fc =1 Hz. Thus it is beneficial to operate VAWT at fc close to 1 Hz. The effect of Tip Speed Ratio is studied by running the simulations at λmean=1.11, 1.3, 1.81, 2 and 2.5. Cycle averaged CP increases with increase in λmean and reaches a maximum value of 0.31 at λmean=2. Further increase in λmean beyond 2, results in a decrease in CP value. The slope of the CP curve is steep for λmean < 2. And for λmean > 2, the slope of the CP curve is gradual. Hence during fluctuating wind analysis, it is beneficial to operate VAWT at λ ≥ mean 2 to obtain a relatively higher CP and steady performance. In a nutshell, the overall performance of VAWT under fluctuating wind conditions is improved by operating at higher Uamp, fc close to 1 Hz and λ ≥ mean 2. When comparing the present results with that of Danao et al., conclusions are contradicting in case of fluctuation amplitude and frequency. Furthermore, Vorticity contours are studied for two planes where Z/H=0.033 and 0.167 respectively from the lower blade tip.Thus blade tip plays a critical role in determining the CP. This emphasizes that 3D simulations are essential to analyze the actual performance of VAWT.
5.	A CFD model for simulating wave run-ups and wave loads in case of different wind turbine foundations	Yu-Hsien Lin, Jing-Fu Chen, Po-Ying Lu	Ocean Engineering	The maximum wave load on the wind turbine foundation is found to decrease with the increase of wave steepness ka. Specifically, lower wave steepness has the most considerable contribution to the maximum wave load on the gravity-based support structure, followed by the tripod and monopile support structures. By means of the installation of sloping bottom on the outlet

	influenced by nonlinear waves [6]			boundary, the incident wave is found to be eliminated physically. Through a series of numerical experiments including different wave heights H0 and periods T0, the reflection rate analyzed by the twopoint method is generally below 0.02 for the subsequent cases of wave-structure interaction. In case of higher wave steepness, foundation type is found to have greater influence on the maximum Ru, Max/a of each support structure. Contrastingly, foundation type has less influence on the minimum Ru, Max/a of each support structure. Generally, the maximum value of Ru, Max/a for each support structure increases accompanied with the increase of wave steepness ka. In comparison, the difference of the minimum Ru, Max/a among each support structure decreases with the increase of ka. For the estimation of run-up heights considering wave kinematics and foundation types, a calibrated run-up parameter m in the semi empirical formula is obtained. The calibrated run-up parameter m decreases with higher values of both the normalized maximum runup parameters Ru, Max/a and wave steepness ka.It is summarized that the estimation of run-ups should be subject to the wave load, especially for the case of lower waves. It can be indicated by higher m values for lower waves than those for higher
6.	CFD simulation of a floating offshore wind turbine system using a variable speed generator-torque controller [7]	Sean Quallen, Tao Xing	Renewable Energy	Results are compared to the publically available OC3 results of NREL using their FAST software. Simulations utilize an incremental approach for verification of the method. OC3 LC 2.1a, featuring a fixed platform and rotor rotational velocity, is first simulated (Case 1) to determine a baseline expectation of rotor torque considering the different aerodynamic solution differences between the present CFD solver and NREL's FAST. The results show about 6% less maximum, minimum, and mean rotor torque than NREL's predictions, within the range of OC3 participants. A second simulation (Case 2) is performed using the conditions of OC3 LC 2.1b. The platform is still fixed, however the inertial rotor model and VS controller are now activated to investigate the effect of torque control on rotor torque. A very consistent difference of 4.4% is seen between Case 2 and NREL's results in each of mean, maximum, and minimum rotor torque, verifying the operation of the VS controller.
7.	Wind tunnel and numerical study of a straight-bladed vertical axis wind turbine in three	Qing'an Li, Takao Maeda, Yasunari Kamada, Junsuke Murata, Toshiaki Kawabata, Kento Shimizu, Tatsuhiko	Energy	According to pressure distribution acting on the center of blade span, it is found that the peak suction is increased and up to CP¼_27.14 at the azimuth angle of q ¼ 90_ when the tip speed ratio is 2.29. Moreover, from x/c ¼ 0.62 to x/c ¼ 1, a rapid reduction in suction over the blade surface

	dimensional analysis (Part I: For predicting aerodynamic loads and performance) [8]	Ogasawara, Alisa Nakai, Takuji Kasuya.		indicates that partial flow separation from the trailing edge, but suction is retained at the upper section of the blade. The maximum value of the negative pressure decreased with the increase of spanwise positions.Furthermore, it must also be noted that the measurement values at the spanwise position of z/(H/2) ¼ 0.55 show different tendency because of the support structure which can generate associated vortex. The maximum values of torque coefficients are about CQS ¼ 0.342, 0.178, 0.226 and 0.181, when the measurements are set on the spanwise positions of z/(H/2) ¼ 0, 0.55, 0.70 and 0.80, respectively. Furthermore, at the center of blade span of z/(H/2) ¼ 0, the torque coefficient is about 50% higher at the maximum, with respect to the other cross sections. it is confirmed that the power coefficient illustrates the maximum value at the blade central height of z/(H/ 2) ¼ 0, and gradually decreases when approaching the blade tip. However, the power coefficient in the spanwise position of z/(H/ 2) ¼ 0.55 also shows the smallest value.It is concluded that power coefficient of the straight-bladed VAWT is significantly improved by reducing the three-dimensional effects on the flow around the blade and the support structure. In our future research, the effect of support structure on power coefficient for wind turbine will be considered in wind tunnel experiment and CFD calculations.
8.	Design and Analysis of Vertical Axis Wind Turbine Rotors [9]	MD. Saddam Hussen,Dr. K. Rambabu, M. Ramji,E. Srinivas.	Design and Analysis of Vertical Axis Wind Turbine Rotors	A comparative evaluation of a small Helical-VAWT and of a Straight-VAWT has been performed. Preliminary three-dimensional CFD analyses have been carried out. Three-dimensional static analyses of three different configurations have been performed. Among these, only two configurations, Straight and twisted 900 were used in the dynamic analyses. From steady simulations, over a complete cycle, it has been observed that the helical blades have an average power output increment equal to 8.75%. This leads the Helical VAWT to a low speed of start-up (this is confirmed by dynamic results at low rotational speed) and then to a higher number of operational hours in similar environmental conditions.For a 3-D comparison, it is shown that this effect is less relevant in the Helical VAWT than in the Straight one.
9.	Cfd Analysis On A Savonius Rotor Wind Turbine Made Using Mild Steel Material [10]	N. Dibakara Reddy, Surender Singh, N. Tejeshwar Reddy	Cfd Analysis On A Savonius Rotor Wind Turbine Made Using Mild Steel Material	The conclusions derived from the CFD analysis are as follows: 1. The Static Pressure obtained in this case **1.468e04Pa** 2. The Dynamic Pressure value obtained is **1.921e04Pa.** 3. The Absolute Pressure obtained in this case is

				11.6e04Pa. 4. The Relative Total Pressure obtained in this case is **1.93e04Pa**. 5. The Relative Total Pressure obtained in this case is **1.9316e04Pa**. The CFD analysis proves that all types of pressure calculated are less than the material maximum value and thus savonius turbines made of mild steel can be used as they provide strength as well as good electrical output. The aspect of strength is tested in this paper and the results are satisfactory.
10.	Performance Analysis of Vertical Axis Wind Turbine with Comparison of CFD and Experimental Analysis [11]	Mayank D. Patel, Tushar P. Gundarneeya	Performance Analysis of Vertical Axis Wind Turbine with Comparison of CFD and Experimental Analysis	CFD is capable of designing the VAWT with higher degree of accuracy. It can also be used for the optimization of blade design. Moreover, flow field around various configurations' blades can also be visualized with the help of CFD. It has not only accelerated the design process of VAWT but also has brought down the overall cost of designing. Various vertical axis wind turbines can offer solution to the energy requirements ranging from 2 kW to 4 MW with a reasonable payback period. Coefficient of power can be maximized by selecting a suitable TSR range for various configurations. The parameter like air strike angle and aerofoil of the blade, wind speed, tip speed ratio, chord length are one of most effecting parameter for the vertical axis wind turbine. By the analysis using this parameter can become useful in the performance optimization of the vertical axis wind turbine.
11.	Experimental and Numerical Study of the Aerodynamic Characteristics of an Archimedes Spiral Wind Turbine Blade [14]	Kyung Chun Kim , Ho Seong Ji , Yoon Kee Kim , Qian Lu , Joon Ho Baek, Rinus Mieremet	Experimental and Numerical Study of the Aerodynamic Characteristics of an Archimedes Spiral Wind Turbine Blade	A new type of HAWT adopting the Archimedes spiral blade format was introduced the full 3D CFD analysis yielded good agreement. The predicted performance characteristics of the 0.5 kW-class Archimedes wind turbine by 3D CFD analysis showed a relatively high power coefficient, Cp = 0.25, compared to the other types of small scale urban usage VAWTs. The averaged and phase averaged velocity fields were obtained using the 2D PIV technique for three different inflow conditions. there was no friction torque, the blade's rotation speed was affected by the inflow velocity. And the maximum pressure differences was observed at the blade tip, so the most wind energy could be extracted from the outer part of the blade. The unsteady CFD simulation showed better agreement with those of the PIV experiments than the steady state simulation.
12.	Double Multiple Stream Tube Model and Numerical Analysis of	Habtamu Beri, Yingxue Yao	Double Multiple Stream Tube Model and Numerical Analysis of	Vertical Axis Wind Turbine with NACA 0018 blade geometry based on fixed pitch three blades was analyzed using double multiple stream tube model. The steady state performance of the modified airfoil was also analyzed at TSR = 0.The

	Vertical Axis Wind Turbine [16]		Vertical Axis Wind Turbine	DMST result shows that the turbine generates negative torque for the lower tip speed ratios. The Computational Fluid Dynamics result shows that the turbine generates positive torque for lower tip speed ratios. The steady state performance at three different orientations also indicates positive torque
13.	Numerical and Analytical Investigation of Vertical Axis Wind Turbine [17]	Asress Mulugeta Biadgo Aleksandar Simonovic Dragan Komarov Slobodan Stupar	Numerical and Analytical Investigation of Vertical Axis Wind Turbine	Both analytical and numerical investigation of performance of Darrius type straight blade VAWT is done using NACA0012 as a blade profile. The *CP* value obtained from the DMST model and CFD were then compared. DMST model overestimated the maximum CP value. The advantage of Computational Fluid Dynamucs is that it provides a platform to explore various airfoil shapes for optimum VAWT performance but it is computationally intensive. Darrieus type straight blade VAWTs are advantageous in several aspects if its inability to self start is resolved.
14.	Vertical Axis Resistance Type Wind Turbines For Use In Buildings [19]	Gerald muller, mark f. Jentsch, euan stoddart	Renewable energy	A modern adaptation of the vertical axis sistan type windmill was investigated looking at its efficiency as an energy converter and its possibilities for architectural integration.Model tests were conducted to test the theory, and efficiencies of 42% for the highest measured power output were determined.
15.	A CFD Study of Wind Turbine Aerodynamics [20]	Chris Kaminsky, Austin Filush, Paul Kasprzak,Wael Mokhtar	A CFD Study of Wind Turbine Aerodynamics	The model of the airfoil in both the 2D and 3D cases allows the user to study the aerodynamics of various geometries at different physical settings to get a true feel for how the specific airfoil might behave in real world applications.The wind speeds of 15 and 30 mph were studied, as well as varying attack angles from 0 to 15 degrees, the results of this research on the NACA 001234 airfoil showed it could be a very viable choice for a residential VAWT. The 2D analysis gave a stall angle of about 8 degrees,the 3D analysis, it being more accurate, did not provide us with a stall angle. Further, analysis would provide more information on the critical angle of attack. The results for the 3D full assembly analysis of vertical axis wind turbine were incomplete. Even though the results yielded were less than desirable, analysis of why the simulations failed proved to be very helpful in the mastery of CFD software use.
16.	Vertical Axis Wind Turbine Performance Prediction, High and Low Fidelity Analysis [23]	Franklyn Kanyako, Isam Janajreh	Vertical Axis Wind Turbine Performance Prediction, High and Low Fidelity Analysis	The results show that the double multiple stream tube model is not suitable for high solidity turbines. It is most suitable for low solidity wind turbines. The CP value obtained from DMST and CFD were compared shows that negative and/or minimum CP and torque are generated at lower tip speed ratios, which implies that NACA 0015, NACA 0018, and NACA 0021 airfoils are not self-starting. NACA0021 has shown to have better starting

				performance than the other two airfoils due to its thicker section. One major advantage of a low-fidelity analysis is that it can be used to determine an appropriate parameter for turbine performance before timely and expensive computation and experimentation.
17.	Modeling and Numerical Simulation of a Vertical Axis Wind Turbine Having Cavity Vanes [12]	Kadhim Suffer , Ryspek Usubamatov , Ghulam Quadir , Khairul Ismail	Modeling and Numerical Simulation of a Vertical Axis Wind Turbine Having Cavity Vanes	The three dimensional numerical investigating of the newly designed of cavity type vertical axis wind turbine is carried out using CFD software GAMBIT with ANSYSFLUENT. Shear Stress Transport (SST) *k*-ω turbulence model is used to predict the aerodynamics of the turbine. the drag coefficient increases with the increase in turbine frontal area and decreases with the decrease in its frontal area, the maximum static pressure drop is found in the case of blade angular position of 90° (14.27e+02 Pa) and minimum in the case when the blade angular position is 45° (6.08e+02 Pa), the velocity in the region of wind turbines rotation was much larger than that of the upstream air flow. There is a wake dispersion region in the downstream of the wind turbine. The results give good agreement when compared with experimental published results.
18.	Conceptual Model of Vertical Axis Wind Turbine and CFD analysis [13]	Dr.P.M.Ghanegaonkar , Ramesh K.Kawade , Sharad Garg	Conceptual Model of Vertical Axis Wind Turbine and CFD analysis	The blade was designed by using Catia software CFD analysis was performed in order to obtain the velocity distribution of the air around the turbine blade and rotation of the blade in rpm for two models for further calculation of torque and power generation as output. From the Computational Fluid Dynamic analysis, it is found that the turbine rotate at 130 rpm for 12 seconds for model without gap between the shaft and blades which is encourage result for further research study for experimental work and do the validation of the turbine by attaching appropriate torque measurement arrangement for power generation. The development of VAWT in India has made significant progress during last 10 years. Due to incremental rate of environmental concern, wind energy development has experienced a significant of interest and considerable attention all over the world. Due to its simple construction and low maintenance cost, VAWTs can be effectively used for generation of electricity in India.

19	Wind Flow Analysis on a Complex Vertical Axis Wind Turbine Using CFD [21]	C.Pradeepkumar, J.Jayaraj, P.Tamizhselvan, M.Soundararajan, M.Magudeswaran.	Wind Flow Analysis on a Complex Vertical Axis Wind Turbine Using CFD	Use of small wind turbines for power generation will be a solution for the upcoming energy crisis. For that the vertical axis wind turbines are suitable for small scale domestic power generation. The fabricated vertical axis wind turbine have swept area of (s) =0.35 m2 Available power in the wind is = 300.125 watt. Power co-efficient for VAWT= 0.55 Power captured by turbine blades = 150 watt Solidity= 0.64 (If solidity is greater than0.4, then the turbine is self-starting)
20	Dynamic stall for a Vertical Axis Wind Turbine in a two-dimensional study [22]	R. Nobile, M. Vahdati, J. Barlow, A. Mewburn-Crook	Dynamic stall for a Vertical Axis Wind Turbine in a two-dimensional study	Three RANS turbulence models have been explored for the four cases analyzed at low TSRs there is an increase in the number of intersection points especially for negative angles of attacks that can be related to deep dynamic stall In this numerical study, the analysis has proved the presence of two different phenomena called dynamic and static stall that are highly depended on the TSRs adopted. In here the SST model is examined in terms of vorticity distributions around the blades turbulence methods that seem to be more dissipative the method is able to show the main four phases involved during dynamic stall one important observation for the SST method is the presence of single-vortices instead of having several small vortices that are typically found that around the airfoil for Particle Image Velocimetry dynamic stall tests better improvement can be achieved in the future investigation of a 3-D case where the LES and the DES methods are strongly recommended.

IV. COMPUTATIONAL STUDY

A. Computational Modeling

The majority of wind turbine research is focused efficiency. Various CFD models exist, each with their own strengths and weaknesses that attempt to accurately predict the performance of a wind turbine. Descriptions of the general set of equations that the methods solve can be found in next chapter. This is able to numerically predict wind turbine performance offers a tremendous benefit over classic experimental techniques, the major benefit being that computational studies are more economical than costly experiments. The three major models include momentum models, vortex models, and CFD models. Each of the three models is based on the simple idea of being able to find the relative velocity and in turn, the tangential force component of the individual blades at various azimuthally locations.

B. Computational Fluid Dynamics

CFD has been gaining popularity for analyzing the complex; unsteady aerodynamics involved in the study of wind turbines and has demonstrated an ability to generate results that compare favorably with experimental data. Computational fluid dynamics has shown no problems predicting the performance of either high- or low solidity wind turbines or for various tip speed ratios. It is important to note that predicting the performance of a wind turbine using CFD typically requires large computational domains with sliding interfaces and additional turbulence modeling to capture unsteady affects, CFD can be computationally expensive.

C. Grid Generation

The next step is to discretize the computational domain as a preprocessing step in the CFD process after the geometry for the vertical axis wind turbine. The act of discretizing the domain is termed grid generation and is one of the most important steps in the CFD process. For simple geometries, the direction of the flow is known beforehand, creating the grid is usually straightforward. For flows such as this, high quality structured grids can be used that can accurately capture the flow physics.

Merits of Vertical Axis Wind Turbines Over Horizontal Axis Wind Turbines.

PARAMETERS	VERTICAL AXIS WIND TURBINE	HORIZONTAL AXIS WIND TURBINE
Tower Sway	Small	Large
Yaw Mechanism	No	Yes
Self Starting	No	Yes
Overall Formation	Simple	Complex
Generator Location	On Ground	Not On Ground
Height From Ground	Small	Large
Blade's Operation Space	Small	Large
Noise Produced	Less	High
Wind Direction	Independent	Dependent
Obstruction For Birds	Less	High
Ideal Efficiency	More Than 70%	50-60%

Table no 1**:** Merits of Vertical Axis Wind Turbines Over Horizontal Axis Wind Turbines.

V. CONCLUSION

Over last two decades due to lack of develoment and economically viable energy solutions for remote areas which is away from integrated grid systems,the various problems associated like poor building integration ,poor self starting and low coefficient of power, VAWT has significant advantages over HAWT.

VAWT can give solution to energy requirements ranging from 2kw to 4kw also coefficient of power can be increased with the selection a suitable TSR range for various configurations. The urban rooftop installation will interpret highly unstable turbulent wind flow patterns but VAWT being axis symmetric they are unidirectional turbines that respond well to changes in wind flow.

For predicting the performance accurately of VAWT many computational models that can numerically verify the performance of wind turbine numerically and delivers a great benifit over classic experimental technique

REFERENCE

[1]. P.Larin , M.Paraschivoiu,C.Aygun - Journal of Wind Engineering and Industrial Aerodynamics, J. Wind Eng. Ind. Aerodyn. 156 (2016)
[2]. San-Yih Lin, Yang-You Lin, Chi-Jeng Bai, Wei-Cheng Wang - Performance analysis of vertical-axis-wind-
[3]. turbine blade with modified trailing edge through computational fluid dynamics, Renewable Energy (2016).
[4]. P.-L. Delafin, T. Nishino, A. Kolios, L. Wang - Comparison of low-order aerodynamic models and RANS CFD for full scale 3D vertical axis wind turbines, Renewable Energy (2017).
[5]. Natapol Korprasertsak, Thananchai Leephakpreeda - Analysis and optimal design of wind boosters for Vertical Axis Wind Turbines at low wind speed, Journal of Wind Engineering and Industrial Aerodynamics , J. Wind Eng. Ind. Aerodyn. (2016)

[6]. M.M.S.R.S. Bhargava, Velamati Ratna Kishorea, Vaitla Laxman - Influence of fluctuating wind conditions on vertical axis wind turbine using a three dimensional CFD model , J. Wind Eng. Ind. Aerodyn. (2016).
[7]. Yu-Hsien Lin, Jing-Fu Chena, Po-Ying Lu - A CFD model for simulating wave run-ups and wave loads in case of different wind turbine foundations influenced by nonlinear waves, Ocean Engineering (2017)
[8]. Sean Quallen, Tao Xing- CFD simulation of a floating offshore wind turbine system using avariable-speed generator-torque controller, Renewable Energy 97 (2016)
[9]. Qing'an Li,Takao Maeda ,Yasunari Kamada, Junsuke Murata,Toshiaki Kawabata,Kento Shimizu,Tatsuhiko Ogasawara,Alisa Nakai,Takuji Kasuya - Wind tunnel and numerical study of a straight-bladed vertical axis wind turbine in three-dimensional analysis (Part I: For predicting aerodynamic loads and performance) , Energy(2016).
[10]. MD. Saddam Hussen, Dr. K. Rambabu,M. Ramji, E. Srinivas - Design and Analysis of Vertical Axis Wind Turbine Rotors.
[11]. N. Dibakara Reddy , Surender Singh, N.Tejeshwar Reddy – CFD analysis on a savonious rotor wind turbine made using mild steel.
[12]. Mayank D . Patel, Tushar. P. Gundarneeya – Performance analaysis of vertical wind axis turbine with comparison of CFD and experimental anlaysis.
[13]. Kadhim Suffer, Ryspek Usubamatov, Ghulam Quadir , Khairul Ismail - Modeling and Numerical Simulation of a Vertical Axis Wind Turbine Having Cavity Vanes ,2014.
[14]. Dr.P.M.Ghanegaonkar , Ramesh K.Kawade , Sharad Garg - Conceptual Model of Vertical Axis Wind Turbine and CFD analysis, May 2014.
[15]. Kyung Chun Kim, Ho Seong Ji, Yoon Kee kim, Qian Lu, Joon Ho Back, Rinus Mieremet- Experimental and Numerical study of the Aerodynamic characteristics of an Archimedes Spiral Wind turbine Blade, 2014.
[16]. Shrikant D. Had e, Mahesh R. Chopade, Ajay Malashe – Vertical Axis Wind Turbines (VAWT) and Computatinal Fluid Dynamics (CFD) : A Review, May 2014.
[17]. Habtamu Beri, Yingxue Yao - Double Multiple Stream Tube Model and Numerical Analysis of Vertical Axis Wind Turbine,2011.
[18]. Asress Mulugeta Biadgo, Aleksandar Simonovic, Dragan Komarov, Slobodan Stupar - Numerical and Analytical Investigation of Vertical Axis Wind Turbine.
[19]. Muhammad Mahmood Aslam Bhutta*, Nasir Hayat, Ahmed Uzair Farooq, Zain Ali, Sh. Rehan Jamil, Zahid Hussain , Vertical axis wind turbine – A review of various configurations and design techniques, Renewable and Sustainable Energy Reviews (2012).
[20]. Gerald Muller, Mark F. Jentsch, Euan Stoddart - Vertical axis resistance type wind turbines for use in buildings, Renewable Energy 34 (2009).
[21]. Chris Kaminsky, Austin Filush, Paul Kasprzak and Wael Mokhtar - A CFD Study of Wind Turbine Aerodynamics.
[22]. C.Pradeepkumar, J.Jayaraj, P.Tamizhselvan, M.Soundararajan, M.Magudeswaran - Wind Flow Analysis on a Complex Vertical Axis Wind Turbine Using CFD.
[23]. R. Nobile, M. Vahdati, J. Barlow, A. Mewburn-Crook - Dynamic stall for a Vertical Axis Wind Turbine in a two-dimensional study, may 2011.
[24]. Franklyn Kanyako,Isam Janajreh- Vertical Axis Wind Turbine Performance Prediction, High and Low Fidelity Analysis.