Review on CFD Analysis of Vertical Axis Wind Energy Conversion System Using Performance Parameters

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Abstract: As we know that wind energy is one of the best sources of free energy which can be used for the production of power. But this method has a high cost and low yield. So, the objective of this project will be to determine the various factors which are affecting the efficiency of the VAWT (GIRO MILL) such that we can design it for a better efficiency. It can be done by various methods like Numerical approach, computer fluid dynamics, wind tunnel experiments but the main factor which affects is the cost. In this paper we tried to review some of good research in field of CFD Analysis of Vertical Axis Wind Energy Conversion System Using Performance Parameters.

***Index Terms* – Vertical Axis Wind Energy Conversion System, Wind Turbine, Performance, Renewable Energy Sources**

I. INTRODUCTION:

We know that fossil fuels are the limited source of energy and they are going to be exhausted soon and the main thing is that they are having a negative impact on environment they release co2 which is increasing the chances of global warning, keeping in mind about all the problems scientist found the better alternatives like to utilize the wind energy, solar energy. Wind energy is an unlimited source of energy which if harnessed properly will get the mankind devoid of using the conventional sources of energy. This project has been designed keeping this in view to make the harnessing of wind energy more efficiently. The best way to utilize the wind energy is the wind turbine. The present project discloses a vertical axis high speed wind turbine provided with rotational speed control systems. This vertical axis wind turbine is formed by having blades of a proper airfoil fitted to respective supporting arms provided radially from a vertical rotating shaft by keeping the blade span-wise direction in parallel with the shaft and being provided with aerodynamic control elements operating manually or automatically to control the rotational speed of the turbine. The kinetic energy of the wind can be changed into other forms of energy, either mechanical energy or electrical energy. The kinetic energy contained in wind can be transferred to other objects, such as boat sails, or transformed into electrical energy through wind turbine generators. With the recent surge in fossil fuels prices, demands for cleaner energy sources, and government funding incentives, wind turbines are becoming a more viable technology for electrical power generation. All wind turbines essentially work the same way with minor modifications depending on size and configuration. The wind turns the blades to spin a shaft which connects to a generator which produces electricity. Essentially the rotors harness the kinetic energy of the wind and coverts it into electrical energy. Wind turbines are largely divided into vertical axis wind turbines and propeller (horizontal axis) wind turbines.

II. LITERATURE REVIEW:

2.1 Design of Blade

Has proposed that design plays an important role for the development of a VAWT it present a mean for reducing the torque variation during the revolution of VAWT by increasing the blade number The aim of the present work is to numerically analyze the aero dynamics behavior of 3, 4 and 5 darrieus VAWT operating at different angular velocities for constant wind speed 9m/s. In particular the discretization of the computational domain into macro areas led to two districts sub grids. CFD, VAWT, NACA0021, blade number it also gave us a brief that If the blade number is increased the oscillation of Ct are reduced while its average value remain almost constant numerical analysis were performed in order to understand the effect of blade number on the behavior of straight-blade VAWT. Large number of blade allowed to reach the maximum power co- efficient for lower angular velocities but was penalized as far as efficiency is concerned. 34% of EU's total electricity consumption will come from renewable energy source, with wind energy accounting for 14%. In this scenario, the research in wind energy system acquires considerable important. [1]

They had given in the paper is that the current capabilities and limitations of aerodynamic models with emphasis on double multiple stream tube model as a design tool. An enhanced performance of VAWT through a vertical pitch for straight-blade rotor to regulate dynamic stall regime. The main result is new inverse design tool has been developed to optimize VAWT performance using a genetic algorithm in conjunction with the CARDAAV code. It means that performance prediction of Sandia 17m wind turbine using CARDAA code was improved by considering the variable interference factor and by including stream tube expansion effect. Based on the result, which are much closed to vortex model result. The simulation of the dynamic stall hysteresis loop using 3DVF code with indicial model. CARDAAV prediction in the upwind and downwind regions of the turbine agrees well with experimental data. The development of the different state of art numerical tools for simulating the flow field around the VAWT as well as the dynamic stall phenomenon are based on method that can be divided into 4 major categories (i) momentum modes, (ii)vortex models, (iii) local circulation models, (iv) viscous models. Blade aerodynamic, dynamics stall, models(mathematical), numerical method, navier-stocks equation, and wind turbine are key findings. During the research the author told us about the importance of the conventional source of energy stating the VAWT and its affecting factors , and also stated that the design plays an important role in the performance. [2]

In this paper the author has reviewed the research on VAWTs. The VAWT studies were focused on the aerodynamic of airfoil, modeling, design effectiveness in the unstable wind, project feasibility, self-start capability, and integration with the grid systems. WTs converted wind energy into electricity and generated about 4% of global electricity by the end of 2016. An astonishing growth has been seen in the last decade in the acceptance of WTs. The performances of WTs on onshore and offshore projects are meeting or exceeding the expectations, and grid parity has been reached with conventional electricity in many parts of the world. Despite the phenomenal growth, the acceptance of WTs for urban applications is still evolving and achieved a limited to no acceptance. Urban WTs have several advantages, viz. the generation of electricity at the points of applications, no transmission and distribution losses, eliminate the dependency of grid electricity, support decentralized power, reduce GHG emissions b and support sustainable development. Over the last three decades, several designs of urban WTs have been proposed, modeled, tested and implemented, and some of them have achieved partial success, viz. Savonious and Darrieus. This paper has reviewed the research on VAWTs. The VAWT studies were focused on the aerodynamic of airfoil, modeling, design effectiveness in the unstable wind, project feasibility, self-start capability, and integration with the grid systems. The limited acceptance of VAWTs is due to the incomplete reliable long-term performance data, and the absence of precise resource assessment tools. Several companies are manufacturing, designing, and developing projects based on VAWTs; however, the bulk of existing market is in the USA, Europe, and China. VAWTs are showing potential, and their acceptance will improve further as technology advances, the cost will reduce, and more people will be aware of the scope of these turbines to reduce their energy bills and carbon footprint. It was concluded that further research is crucial in making VAWTs a viable, dependable, and affordable power solution for many low demand applications, off-grid sites, and for two billion peoples without the access of minimum level of electricity. [3]

2.2 Analysis of Blade and Rotor:

Paper has proposed in this paper that the Orthopter-type Vertical Axis Wind Turbines (O-VAWT) in urban areas. This paper aims to study the effect of number of blades (solidity), Aspect Ratio (AR), .3and wind speed on the performance of a small-scale O-VAWT using experimental and numerical techniques. Wind tunnel experiments were carried out to measure the torque of two-, three, and four-bladed turbine, each at a set of different wind speeds and blade aspect ratios. Increasing solidity was achieved by either decreasing the blade aspect ratio or increasing the number of blades, both resulting in a higher peak power coefficient (Cp max) of the VAWT. The startup characteristics of the O-VAWT were also examined at different aspect ratios, and showed its capability to start-up even at low wind speeds. Moreover, velocity and vorticity contours for the two-, three-, and four-bladed turbines, and pressure contours at different span-wise locations were thoroughly analyzed to link the flow field aerodynamics to relevant changes in power coefficient for different rotor solidities. The author tests O-VAWTs with number of blades ranging from 2 to 4, and aspect ratios of 0.899, 1, 1.06, 1.5 and 2, in a wind tunnel at wind speeds of 5 and 10 m/s. Additionally, DDES using Spalart Allmaras model were performed at the latter wind speed. Following a close agreement between CFD and experimental results, the effect of solidity, aspect ratio and wind speed on the turbine performance was examined. The major findings is that the maximum power coefficient attained by the turbine increases with solidity, an increase in aspect ratio, while retaining the same number of blades, results in a decrease in Cp,max, The TSR corresponding to Cp,max increases at higher wind speeds, the O-VAWT is able to start-up at lower wind speeds compared to typical S-VAWT, for an incoming wind speed of 10 m/s, differences in instantaneous flow structures between the two- and three-bladed turbines were substantial and therefore, leading to a significant change in the average power coefficient produced. [3]

Paper has given his time in his research for analysis of savonius type VAWT keeping in mind about all the problems. This project has been designed keeping this in view to make the harnessing of savonious type VAWT energy more efficiently. The main aim is to find the problems which a savonius type VAWT is facing and to find the solution for their elimination. During the research the authors proposed various methodology and found the cheapest one and finally analysed the various factors and found the results on individual basis and proposed various factors which were affecting the efficiency of the turbine. They had given that the three bladed savonius turbine has best performance at high tip speed ratio and four bladed savonius turbine has good performance at lower tip speed ratio. If wind is coming from different direction then four blade turbine is more efficient over conventional one. The VAWT is simply a device which converts wind energy into electric energy using electric motor. Wind energy is an unlimited source of energy which if harnessed properly will get the mankind devoid of using the conventional sources of energy. [4]

2.3 Aerodynamics Modelling

Paper has described the analysis of the aerofoil and found the drag forces, he also stated that the blade design plays an important role in the efficiency of the turbine. In the beginning the author selected the aerofoil blade of NACA 0012 aN they just gave the explanation about nomenclature of the foil and explained many terms such as trailing edge, leading edge, trail line etc. then the authors simply selected the boundary conditions for the analysis during this they gave explanation about the boundary conditions and how they are taken after it they gave a brief about the processes which a CFD analysis follows .then after meshing is done , meshing is a process under which the component is divide into small elements. Once mesh got generated various contours were plotted based on the static pressure and velocity magnitude over NACA 0012. And in the authors concluded that the zero degree the angle of attack there is no lift force generated and if we want to increase amount of lift force and value of lift coefficient then we have to increase the value of angle of attack by doing that the amount of drag force and its coefficient will increase but the increment n drag force is quit less as compared to lift force. [5]

Paper gives an explanation about the high values of centrifugal forces which plays an important role in the design of the straight blades of VAWT and also defined how this can be reduced by using different materials like aluminum, glass epoxy. A better efficiency can be obtained by reducing the deflections and the stresses on it by analyzing the high applied loads and weight ratio is obtained by reducing the centrifugal forces, maximum deflections and maximum stresses in the composite blade. It has been seen that the centrifugal force plays an important role in the design of a VAWT blades. Bending stresses and deflections are not only functions of aerodynamic forces but of centrifugal forces too .In order to model the composite materials in any finite element software the layered shell elements should be preferably be used instead of layered solid elements . SHELL elements are more compatible with complex geometry which have sharp edges, produce equally good results and require less computational time as compared to solid elements. [6]

The author in this paper has taken three different blades profiles (EPPLER863, EPPLER863 with one fourth trailing edge removed, Lenz2) for analysis. He founds that as the blade of VAWT rotates it is acted upon by two components of wind force namely lift component which is vertical component and drag component which is horizontal component of wind force. Both the components of incident wind force are mutually perpendicular. While lift is the major component driving HAWT, drag does the needful in this case of VAWT. Drag force is the main driving force for Vertical Axis Wind Turbines, which depends on the shape of the object and it increases with the area facing the wind. The drag force also depends on the density of air and increases with the square of velocity of incoming air. He then says it can be inferred that the only values subject to significant manipulation are coefficients of lift and drag as density of air and surface area of aerodynamic blades are constants and velocity of incoming air will not vary significantly under normal conditions. That is why, to increase drag force significantly, we must increase the value of drag coefficient. [7]

The author gave a brief about the history of VAWT and stated that Savonius rotor is the biggest achievement of Finnish inventor Sigurd Johannes Savonius, who patented it in 1927 (Savonius, 1931). The typical Savonius rotor is equipped with two buckets; however, three or more buckets are possible. It usually has an S-shape cross-section. The Savonius-type wind turbine can achieve even 30% of the maximum power coefficient comparing with 60% from Betz theory the factors which were playing a major role in affecting the performance of VAWT, then he gave description about the methodology and explained that how it is different from the other ones. He also explained how the previous have been made by the other authors for the same problem he also used some references which played an important role in the research. He described the drag force, side force and gave a quick explanation of fluid flow equation. The analysis was made by CFD and calculated various results on the factors like tip speed ratio, side force, Reynolds number, gap length and the results shows that for tip speed ratio, The maximum values of the torque coefficient are approximately 0.6 for each tip speed ratio except for the torque coefficient for the tip speed of 0.6.However, the average value of the torque coefficient decreases as the tip speed ratio increases. For gap length, the power coefficient is higher for the dimensionless gap width of 0.1 in comparison with the gap width of 0.2.For the effect of the Reynolds number, the performance of the Savonius rotor is computed for two velocities of wind, v of 7m/s and 14m/s. As it is observed that the efficiency of the Savonius rotor is slightly larger for the wind speed of 7m/s in comparison with the results for the wind speed of 14m/s. For the Influence of the side force: the mean value of drag force is similar for all tip speed ratios while the average value of the side force coefficient increases with an increase in the tip speed ratio. For the tip speed ratio of 0.4, the mean value of the side force coefficient is about two times lower in comparison with the drag force coefficient. This conclusion is important from the viewpoint of the design of bearings and dynamics of the shaft. According to the results of this research, it can be concluded that the side force acting on the Savonius rotor can be in the same order of magnitude as the drag force, depending on the tip speed ratio. This all analysis helped us in analyzing the effect of following factors and making us understand about it. [8]

It Started with the description of the VAWT and what are the problems due to which it is not able to make the required complimentary or the market. Then the author explained that about the methods both the LOM and the CFD model were employed in predicting the VAWT aerodynamic efficiency in the research. It was established 3D effects must be included to provide an accurate prediction of VAWT performance especially at high TSRs. For VAWT analysts, modeling recommendations and limitations are discussed regarding the LOM. Then he stated that how this methodology is different from the other ones. He created a LOM using different parameters. Further he used CFD for analyzing the different calculations like Azimuth angle for different values then he made Comparison of CFD and LOM simulations with & without the tower model at 2.20 and 4.60. he used DMS model from the open literature and examined it and he showed that higher deviations were made as compared to the CFD model and LOM for the blade normal forces in the aforementioned TSR range. The LOM and CFD model predictions were also compared with the SNL VAWT tangential blade force measurements. From an qualitative analysis, it was showed the LOM and the CFD model predicted the occurrence of the upwind and downwind peaks in the blade tangential force coefficient. It was noted the CFD model predicted the onset of dynamic stall later compared to the LOM and the experimental measurements. Subsequently, the CFD model upwind maximum tangential coefficient was larger than the experimental measurements when dynamic stall occurred. [9]

It Has given the research about the dynamic thrust and radial forces when they rotate. The dynamic loading on the blades of the turbine, as they rotate about the central shaft travel through the range of relative angles of attack, is expected to produce significant deflection of the turbine blades. Appreciable noise generation as well as increase in the potential for fatigue explores the dynamic tangential and radial force on the single turbine blade through the use of CFD simulation. Transient simulation are the more than compared to a set of quasi-steady state result. From this comparison, it is clear that the steady state test do not adequately capture the complex dynamic behavior of the flow over blade. From the practical he can concluded that result obtained from the transient simulation are then compared to a set of quasi-steady result. It is clear that the steady state test do not adequately capture the complex dynamic behavior of the flow over the blade. Another conclusions is that steady state approximation of the dynamic flow behavior predicts the general trends and relative magnitudes effectively but it is unable to fully capture the complexity of the flow. Additionally majority of the lift and drag forces on the blades are in the radial direction. [10]

Paper has proposed that the development of wind energy use in urban environment is of growing interest to industry and local government as an alternative to utility based and nonrenewable to utility based and nonrenewable forms of electric production. He given experimental determination of the nominal power curves and determination of the structural integrity safety and operation characteristics of the system in this full scale wind turbines testing of prototype 3.5KW VAWT supplied energy corporation was conducted on the NRC 9m×9m low speed wind tunnel in Ottawa. Turbine is a 3-blade H-type Darrieus with a diameter of 2.5m and height of 3m. Blades have NACA0015 profile with chord 0.4m the test was designed such that the operation envelope of the turbine would be slowly expanded. Started at the lowest wind speed and RPM. The generator and control system based on the electrical power produced and load applied were still under development during these test. Consequently, to test the turbine and control and instrumentation system had to be added to VAWT Test specimen which are following: (i) turbine speed measurement, (ii) torque measurement, (iii) closed loop speed control system. From this experiment, it was derived that turbine is able to reach it's rated power at 14m/s. Minimum wind speed needed for power production was 6m/s, the turbine was tested operational up to a wind speed of 16m/s and with the locked rotor puro 20m/s. The maximum power co-efficient obtained during testing was approximately 0.3 at a tip speed ratio of 1.6. [11]

They had given us the information all about the research done by him on the aspects for VAWT. The main aim of the paper is to define techniques that help to clarify the balance between rotor life expectancy and the rate of energy production. Rotor control parameters (such as the cut in and cutout wind speeds) should be selected to maximize both turbine life and rate of energy capture. Because the turbine operates in a random loading environment, a statically approach to defining the operating stress is used. This approach allows the analyst to visualize the effect of changing algorithm parameters on the fatigue life and energy production rate of turbine. It is important to remember that the fatigue life and energy capture of a turbine are inseparable components of a cost of energy estimate, good cutout algorithm can reduce the damage significantly without crippling the system by overly restricted the annual energy production. the use of these density function should aid the analyst in visualizing the fatigue life/energy capture trade off. The main result obtained by this paper is an increase in fatigue life caused by restricted operation in certain wind regimes is readily visualized. [12]

Has given about the aerodynamic characteristics such as coefficient of lift and coefficient of drag are evaluated from 00 to 3600. He studies the airfoil characteristics from 00 to 3600 α is necessary in order to improve the performance. The resulting effect of this changing angle is a difference, a hysteresis, in the lift, drag and moment characteristics between increasing and decreasing angle of incidence. The author concludes that behavior of the airfoil from α value of 500 to 2000 with regard to the CL variation shows a similar pattern in comparison to its experimental counterparts. The behavior of the airfoil from α value of 500 to 2000 with regard to the CL variation shows a similar pattern in comparison to its experimental counterpart. The CL variation shows similar pattern from α value of 2500upto 3600. This model can be used to predict to a certain extent the post stall characteristics of the airfoil. Although without the viscous term, it becomes more of a prediction rather than an exact value. This method is useful to maximize the lift during a rotation and determine a better positioning of the blades in a VAWT. Due to lack of accuracy with respect to its behavior of CD, we can use this only for lift based VAWTs and not drag based VAWTs. [13]

In this paper the author has reviewed the research on VAWTs. The VAWT studies were focused on the aerodynamic of airfoil, modeling, design effectiveness in the unstable wind, project feasibility, self-start capability, and integration with the grid systems. VAWTs converted wind energy into electricity and generated about 4% of global electricity by the end of 2016. An astonishing growth has been seen in the last decade in the acceptance of WTs. The performances of WTs on onshore and offshore projects are meeting or exceeding the expectations, and grid parity has been reached with conventional electricity in many parts of the world. Despite the phenomenal growth, the acceptance of WTs for urban applications is still evolving and achieved a limited to no acceptance. Urban WTs have several advantages, viz. the generation of electricity at the points of applications, no transmission and distribution losses, eliminate the dependency of grid electricity, support decentralized power, reduce GHG emissions b and support sustainable development. Over the last three decades, several designs of urban WTs have been proposed, modeled, tested and implemented, and some of them have achieved partial success, viz. Savonious and Darrieus. This paper has reviewed the research on VAWTs. The VAWT studies were focused on the aerodynamic of airfoil, modeling, and design effectiveness in the unstable wind, project feasibility, self-start capability, and integration with the grid systems. The limited acceptance of VAWTs is due to the incomplete reliable long-term performance data, and the absence of precise resource assessment tools. Several companies are manufacturing, designing, and developing projects based on VAWTs; however, the bulk of existing market is in the USA, Europe, and China. VAWTs are showing potential, and their acceptance will improve further as technology advances, the cost will reduce, and more people will be aware of the scope of these turbines to reduce their energy bills and carbon footprint. It was concluded that further research is crucial in making VAWTs a viable, dependable, and affordable power solution for many low demand applications, off-grid sites, and for two billion peoples without the access of minimum level of electricity. [14]

III. CONCLUSION:

The defined techniques that help to clarify the balance between rotor life expectancy and the rate of energy production. Rotor control parameters (such as the cut in and cut-out wind speeds) should be selected to maximize both turbine life and rate of energy capture. Because the turbine operates in a random loading environment, a statically approach to defining the operating stress is used. This approach allows the analyst to visualize the effect of changing algorithm parameters on the fatigue life and energy production rate of turbine. It is important to remember that the fatigue life and energy capture of a turbine are inseparable components of a cost of energy estimate, good cut-out algorithm can reduce the damage significantly without crippling the system by overly restricted the annual energy production. The use of this density function should aid the analyst in visualizing the fatigue life/energy capture trade off. Drag force is the main driving force for Vertical Axis Wind Turbines, which depends on the shape of the object and it increases with the area facing the wind. The drag force also depends on the density of air and increases with the square of velocity of incoming air. He then says it can be inferred that the only values subject to significant manipulation are coefficients of lift and drag as density of air and surface area of aerodynamic blades are constants and velocity of incoming air will not vary significantly under normal conditions. That is why, to increase drag force significantly, we must increase the value of drag coefficient (CD). The performances of WTs on onshore and offshore projects are meeting or exceeding the expectations, and grid parity has been reached with conventional electricity in many parts of the world. Despite the phenomenal growth, the acceptance of WTs for urban applications is still evolving and achieved a limited to no acceptance. Urban WTs have several advantages, viz. the generation of electricity at the points of applications, no transmission and distribution losses, eliminate the dependency of grid electricity, support decentralized power, reduce GHG emissions b and support sustainable development. Over the last three decades, several designs of urban WTs have been proposed, modeled, tested and implemented, and some of them have achieved partial success, viz. Savonious and Darrieus. This paper has reviewed the research on VAWTs. The VAWT studies were focused on the aerodynamic of airfoil, modeling, and design effectiveness in the unstable wind, project feasibility, self-start capability, and integration with the grid systems.

IV. SCOPE FOR FUTURE WORK

- Further New Design Can Be Offered.
- Further Modification By Changing Different Factors Can Be Made For Increasing Cp.

V. REFERENCES

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