A Review Paper based on Vertical Axis Wind Turbine for Design and Performances to Generate Electricity

Bhushan Save

Department of Electrical engineering, VIVA Institute of Technology, Virar east 40305

Abstract—*The wind power energy production is considered as one of the oldest method of generating renewable energy. This can be effectively to use to reduce the consumption of fossil fuel. This paper takes review of how the wind energy on highways can be used to generate electricity, which can be used to provide supply to lights on the same highway or nearby small ruler area. This is the way to produce electricity in more echo friendly way. A new design of vertical axis wind turbine is revived in this paper for its performance and design. This vertical turbine can be installed in-between divider on highways. This also offers promising solution for residential spaces or smaller ruler areas. This will check and optimize design parameters of vertical axis turbine.*

Keywords—Renewable energy, vertical axis turbines, wind energy, Energy sources, clean energy.

I. INTRODUCTION

From las fed decades the need of clean and green energy is at the peak level due to increased pollution levels in cities. Wind can be considered as the secondary form of solar energy and can be always replenished by the sun energy. The kinetic energy of wind is converted into electricity. This is dependent on differential heating of earth surface. The best ecological option can be wind energy. It can be also considered as sustainable. Different wind turbine structures are designed and analyzed by scientist. The comparison these designers and detailed studied of vertical axis wind turbine (VHWT) is done in this paper. The optimum conditions required for operation of this type of turbines are determined. Major benefit of VAWTs id omni-directional wind from any direction is capable of achieving its rotation. So it can be installed in lesser space and same output can be obtained.

1.1 Wind Energy Senario in World

The focus to generate the energy form renewable sources has increased to great extent during recent years. This has been a major issue due to the pollution level increased by CO2 emission. Similarly due to increased demand in energy consumption it's required to find different other option for energy generation. Hence extensive research have been carried out to improve the way in which electricity can be generate by using cheaper ways and more sustainable ways. Wind energy seems to be one of the great option in suitable areas to take care of few percentage of electricity requirements. The great potential existing in the world can be utilized effectively to meet this additional requirement.

To extract energy out of find, wind turbines are designed such that they can convert the motion of wind into rotation of turbine to obtain electricity. Current research technique are focusing on designing on more efficient and lightweight blades to obtain the same. The annual energy output has been significantly increased due to the research imprudent in this area the weight of turbine blade and the noise produce by them has been reduced to the noticeable level in past few years. Indian renewable energy development (IREDA) and the wind industry have been working together to achieve the goals together, Figure 1 shows the existing velocity of the wind at different locations into the world. The area where the more possibilities of production of wind energy, already work has been started to produce energy form wind by installing wind turbine plants to meet the additional energy requirements. Wind power is one of the fastest growing way to produce the energy and the effectively utilized source. Figure 2 makes it clear that the installed capacity of wind turbine has been increased to a very high level in past few decades. It increased form 25,000MW to 200,000 Mw on a single decade. Also the vertical axis wind turbine was the first choice

International Journal of Engineering Research & Science (IJOER)
ISBN: [978-93-5321-411-1] ISSN: [2395-6992] [Vol-5, Issue-3, March- 2019]

forharnessing the energy, researcher have lost theirinterest in this area due to the initial perception that VAWT cannot be implemented for large scale areas.

Horizontal axis wind turbine became more popular choice due to their efficiency and output.This was taken as interested area of research during the installation of t practical plants. The research over the vertical wind turbine was significantly low during this time, maximum plants were installed in the favor of horizontal axis wind turbine. However the additional research in vertical axis wind turbine was carried out parallel to the same has improved the initial results shown by the same. Researchers developed different models to improve efficiency of the VHWT. Optimal conditions were found the suitable for improving the efficiency VHWT.

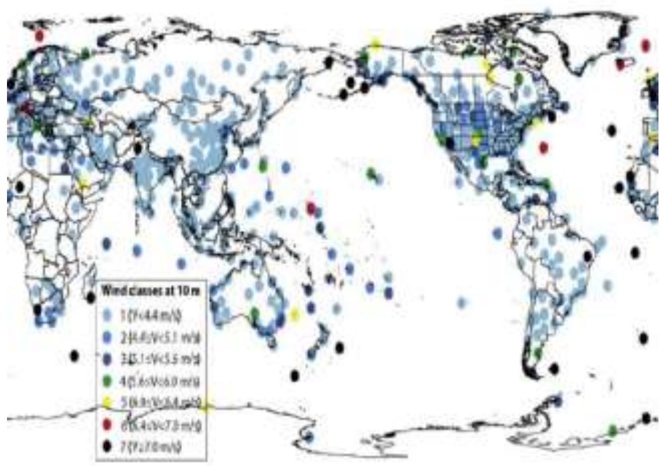

Fig.1 Velocity of wind in various part of world

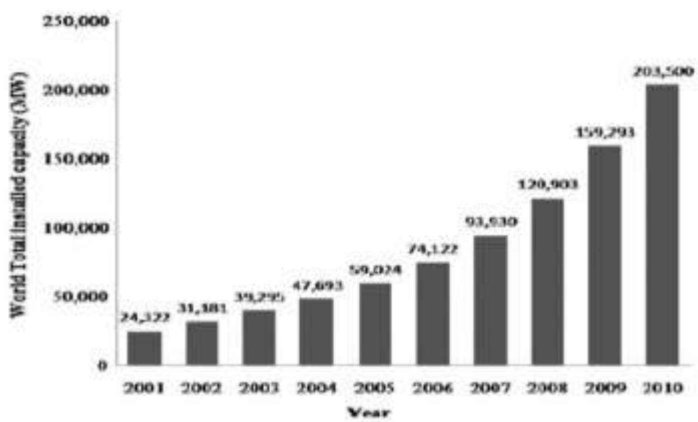

Fig.2 Installed wind potential of world

1.2 Wind energy scenario in India

During 1783-84 wind energy program was started in India. This was 6^{th} five yearly plan. It has been increased significantly during past few years. It was started with the objective of commercialization of wind generation and to motivate the research in that same area. It was also expected to develop interest that area and to create awareness. Ministry of nonrenewable energy (MNRE) has created various schemes and announced many incentives for wind energy under the same program. Tough India was

7th National Conference on
"Role of Engineers in Nation Building" organized by VIVA Institute of Technology, Mumbai
(1st and 2nd March 2019)
International Journal of Engineering Research & Science (IJOER)
ISBN: [978-93-5321-411-1] ISSN: [2395-6992] [Vol-5, Issue-3, March- 2019]

new in this area as compared to rest of the world, it has given large support to this area such that it ranked fourth with largest installed wind power capacity. There is continuous progress done in this field and India would be defiantly a leading nation in generation of wind energy.

India is amongst five leading country to generate wind power named s are china Germany, Spain, and India. Total share of these countries together is 73% of global capacities. Capacity of wind power in India has reached 26.9 GW in 2016. Central electricity authority reported a need of about 350-360 GW of total energy. The only resource utilized yet is onshore capacity of wind. So for. India have 7500Km of long costal area, they have not yet appointed there offshore wind source for energy generation.

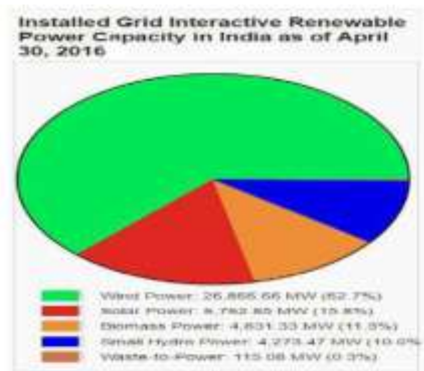

Fig.3 Installed capacity of wind power in India

1.3 Wind farms in india

A. Muppandal-perungudi (Tamil Nadu)

With a total wind power capacity of 1500Mw, this plant has best location of having largest groups of wind turbines which has 35% of India's total capacity in wind generation. Production of electricity was 9.521 billion Kwh which is 15% of CUF.

B. Satara district (Maharastra) and Kavdya Donger, Supa (Maharasrta)

This project was done by worlds leading company Suzlon energy, total capacity of 41767.26 MW it was one of the largest project located near Satara district. This was a limited company who identified the potential of wind energy in this area and installed its project. The cost of land was also one the benefit got by this company as water issues for farming was one the major challenge for farmers. It was easy o to occupy the land in this area. This promise the share of private companies to show the interest in the same area. Total potential OF worth 1500 cores was identified in his area. A wind farm project was installed in Supa area near Pune, Maharasrtra. Total amount of capacity utilization is 22% form this site. This plant has also been coupled through V-SAT by the project developers and sponsors so that they can monitor the performance of total unit. The system implemented id called as SCADA. This was a major revolution in history of Indian wind energy generation.

1.4 different types of design and configurations for vertical axis wind turbine.

The rotational axis is perpendicular to the direction of wind. Due to this the main advantage we will get is the generator can be mounted nearer to ground level. Which provides easy access for maintenance and we do not required to have yaw system for VAWT. This machine is very simple and easy to install and maintain. The major advantage of this is robustness and strong starting torque. It is also possible to rotate this turbine at lower wind speeds. In case of lower wind speeds this machine will produce lesser electricity. During high speed wind conditions this machine is very vulnerable hence the size cannot be increased beyond certain limits.

Types of VAWY's

1. Darrieus type
2. Savonius type
3. Combined Darrieus-savonius
4. H-type Modified H- type.

A. Merits Of VAWT

Major advantage is space occupied by this turbine is less and this is near to ground so no yaw mechanism is required to install. This makes the maintenance work easy and less time consuming. Design are possible with fixed pitch rotor designs. So it can produce electricity with lower speeds of winds. Typically the approximate wind speed to start the generation is observed to be 6M.P.H (10 Km/hr.) VAWT's has been known for their lower noise signature.

B. Demerits of VAWT

Most of the types of this turbine can produce energy with only 50% of the efficiency of HAWT due to large part of additional drag as the blade rotate into wind. In case you need to a change any part of this machine the entire structure has to be disassemble if it has not been designed properly. Due to the its location which is nearer to ground the speed of wind seems to be lower that experienced by HAWT so the VAWT is expected to produce less energy in the same area as compared to HAWT. So this type of turbine is not used in most of the places and HAWT is more preferred over VAWT. This ignorance have caused many investment scams over last few decades.

Table.1
Merits of vertical axis wind turbine over horizontal axis wind turbine

	Horizontal axis wind turbine (HAWT)	Vertical axis wind turbine (VAWT)
Tower sway	Large	Small
Yaw mechanism	Yes	No
Self-starting	Yes	No
Overall Set-up Formation	Complex	Simple
Generator location	Not on ground	On ground
Height from ground	Large	Small
Blade's operation space	Large	Small
Noise produced	high	Relatively Less
Wind direction	Dependent	Independent
Obstruction for birds	High	Less
Ideal efficiency	50–60%	More than 70%

II. PERFORMANCE ANALYSIS ON BLADE DESIGN

A 2m*2m vertical axis wind turbine was integrated and tested by Ryan McGowan et al. with slanted double blades. Predictions of the operating points incorporating multiple stream tube theory and accounting for interactions are validated against published results elsewhere. The predictions shows effect of Reynolds number very clearly, and their appropriate insertion allows the predictions to match experimental data exceptionally well. A self-starting device using drag tubes is included in the simulation. It is found that the vertical axis wind turbine must operate at a tip speed ratio that is considerably greater than 1. Limiting the turbine speed for safety indicates that high tip speed ratio is best gained at low wind speeds by taking the turbine to a good operating speed using human pedalling action or an electric motor. This will permit extraction of considerable amounts of power from the wind compared to what we have been able to achieve using purely self-powered machine operation. With this state of predictions we are in a position to go to detailed time-resolved simulations and thus to control algorithms for adapting to given wind patterns and optimizing power extraction and safety. Young-Tae Lee et al. in article ―Numerical study of the aerodynamic performance of a 500 W Darrieus-type vertical-axis wind turbine studied characteristics and the performance of a Darrieus-type vertical axis wind turbine with NACA airfoil blades. Darrieus-type turbine performance can be characterized by torque and power. Many parameters especially related to blade design have impact on performance of turbine, parameters such as chord length, pitch angle, and rotor diameter etc. To estimate the optimum shape of the Darrieus-type wind turbine in accordance with various design parameters, the separated flow arising in the vicinity of the blade, the interaction between the flow and the blade, and the torque and power characteristics is examined in this review. In this study analyse through, wind tunnel experiment and numerical analysis concluded that Darrieus-type wind turbine with a NACA airfoil blade produces maximum output power with optimized design parameters. Additionally, variations of flow and performance characteristics which act while design parameters are varied were derived numerically. The results of study can be summarized as follows. The thickness ratio of the airfoil blade makes no significant difference in the performance of the wind rotor and turbine considered. However, similar to solidity, a thick airfoil is applied by a greater drag force, which implies to a low power coefficient from turbine. In terms of power performance at varying pitch angles of blades, the highest efficiency occur pitch angle of 2˚. The optimum pitch angle is anticipated to change in accordance with the angle of attack. Conaill Soraghan et al. have investigated the influence of lift to drag ratio on optimal aerodynamic performance of straight blade vertical axis wind turbines .they have reported an effective lift to drag for a VAWT design on the basis of average torque per cycle. This technique is used to characterize the relationship between overall optimum aerodynamic performance and design parameters. A prediction model of double multiple stream tube aerodynamic is employed to prove the effect of lift to drag ratio on optimal power performance for the H-rotor and the V-rotor concept VAWT.This metric can be used to characterize the relationship between overall optimum aerodynamic performance and design parameters. An investigation into the effect of lift to drag ratio on performance of a base case H-rotor revealed that the metric has a significant impact on maximum attainable power coefficient. Bavin Loganathan et al. studied a domestic scale vertical axis wind turbine considering blade geometry with semi-circular shaped blades under a range of wind speeds during operation. A 16-bladed rotor was initially designed and its torques and angular speeds were calculated over a range of wind speeds using a wind tunnel. Furthermore, a new concept of cowling device was established to enhance the turbine efficiency by directing air flow from the rear blades into the atmosphere. Another 8-bladed rotor was also manufactured to examine the effect of blade number on the maximum power generation from turbine. The results of article indicates that the cowling device can be used to increase the power output of this cyclonic type vertical axis wind turbine particularly with a reduce number of blades. It also shows that the wind turbine device has positive effect to increase the rotor speed to a significant amount. The average rotor speed increased by about 26% for the 16-bladed rotor in the comparison of the baseline configuration with implementation if new cowling device. K. Pope et al., an energy and exergy analysis is performed on four different wind power systems considering especially blade performance, including both horizontal and vertical axis wind turbines. Significant variability in turbine designs and operating parameters are involved through the selection of systems. In particular, two airfoils that is blade geometries, generally used in horizontal axis wind turbines are compared with two vertical axis wind turbines. This paper reports thoroughly each system with respect to both the first and second laws of thermodynamics for analysis. The aerodynamic performance of each system is numerically analysed by computational fluid dynamics software in this case FLUENT. Key design variables are analysed and the predicted results are discussed during study. The energetic efficiency of each wind turbine is considered and studied for different geometries, design parameters and operating conditions, thereby providing a useful design tool for wind turbine blade power development. Exergy analysis was shown to allow a various range of geometric and operating designs to be compared with a common metric. As useful parameter in wind power engineering, exergy can characterise a wide variety of turbine operating conditions, with a single unified metric. Better site selection and turbine design can improve system efficiency, decrease economic cost, and increase capacity of wind energy systems through exergy methods.

III. PERFORMANCE ANALYSIS OF VERTICAL AXIS WIND TURBINE BLADES

For harvesting the power of wind turbine, requires a detailed understanding of the physics of the interaction between the moving air and wind turbine rotor blades. An optimal power generation depends on perfect interaction between both blade and wind. The wind consists of a combination of the mean flow as well as turbulent fluctuations about that mean flow. These are very complicated and time consuming for the analysis, and they can only be predicted by understanding the aerodynamics of steady state operation.

3.1 Aerodynamics theory and performance techniques:

The aerodynamic analysis of VAWTs is complex due to their co-ordination to the oncoming wind. The VAWTs have a rotational axis perpendicular to the approaching airflow. This accounts for aerodynamics that is more complicated as compared to a conventional HAWT. On the other hand, the configuration has an independence of wind direction. The main shortfalls of this are the high local angles of attack and the wake coming from the blades in the upwind part and axis. This disadvantage is more pronounced with VAWTs. The power output from the high speed lift VAWT can be appreciable. Understanding the pure drag type of VAWT's aerodynamics will give important insight for improving the lift coefficient, and for better and more efficient designing this turbine harnessing of the wind power.

3.2 DRAG FORCE AND LIFT FORCE

The drag force acts in the direction of the fluid flowing. Drag occurs due to the viscous friction forces on the airfoil surfaces, and the imbalanced pressure on surfaces of the airfoil. Drag as a function of the relative wind velocity at the rotor surface, is the difference between the wind speed and the speed of the surface, the lift and drag coefficient values are usually achieved experimentally and correlated against the Reynolds number for analysis purpose. This work uses a CFD code to predict these coefficient values over a range of operating conditions. The amount of power generated by the vertical axis wind turbine will be analyzed through code. The lift force is one of the major force components exerted on an airfoil blade section inserted in a moving fluid. It acts normal to the fluid flow direction. This force is a consequence of the irregular pressure distribution between the upper and lower blade surfaces. David A. Spera. [16] investigated the Lift and Drag Coefficients of Stalled and Installed Airfoils in Wind Turbines and Wind Tunnels. They have reported a mathematical equation to calculate lift and drag coefficients along the spans of torsional-stiff rotating airfoils of the type used in wind turbine rotors and wind tunnel fans. These airfoils operate in both the uninstalled and stalled aerodynamic regimes, and acceptable models must be able to move seamlessly from one regime to the other. The input factors in the equations defining these models should also be derivable from a minimum of test statistics, because often only a limited number of lift and drag data points in just the pre-stall system are available. Because having finite lengths, wind turbine and fan airfoils, model equations must contain explicit corrections for the effects of aspect ratio of length to chord width on lift and drag. Because the torsion stiffness of a wind turbine airfoil about own longitudinal axis is normally high, airfoil moment coefficients are less significant than lift and drag coefficients, that's why moment coefficients are not addressed in this study.

3.3 CFD analysis:

Research work by Robert Howell presents a combined experimental as well as computational study into the aerodynamics and performance of a small scale VAWT blades. Wind tunnel tests were carried out to ascertain overall performance of the turbine and 2D and 3D unsteady computational fluid dynamics (CFD) models were generated to help and to understand the aerodynamics of this turbine performance. Wind tunnel performance results are given for cases of different wind velocities, tip-speed ratio and solidity along with rotor blade surface finish. It is shown experimentally that the surface roughness present on the turbine rotor blades has a substantial effect on performance of turbine. Below a critical wind speed (Reynolds number of 30,000) the performance of the turbine goes down by a smooth rotor surface finish but above it, the turbine performance is enhanced by a smooth surface finish of blade. Both two bladed and three bladed rotors were tested and a significant increase in performance coefficient is identified for the higher solidity rotors (three bladed rotors) over most of the operating range. Dynamic stalling behavior and the resultant large and rapid changes in force coefficients and the rotor torque are presented to be the likely cause of changes to rotor pitch angle that occurred during early testing. This small change in pitch angle of blade caused significant decreases in performance. Marco Raciti Castelli et al. have Numerical evaluated the aerodynamic and inertial contributions to Darrieus wind turbine blade deformation. The author has presented a model for the evaluation of aerodynamic and inertial contributions to a VAWT blade deformation. Through the use of a specially designed coupling code, solid modelling software, capable of generating the desired blade geometry having dependency on the design geometric parameters, is linked to a finite volume CFD code for the measurement of rotor performance and to a Finite Element Method (FEM) code for the structural design analysis of rotor blades.

3.4 Vortex methods

Wilhelm et al. developed 'Vortex Analytical Model' for aerodynamic load calculations. It measured vortices circulation strength and location that was used to estimate the velocity of air around the rotor at any point. The velocity measurements were then used to measure the rotor performance under different flow conditions. The advantages of this model include its ability to decide blade-wake interactions, estimate results in unsteady flow conditions and for finite aspect ratios of rotor blades. Kopeika and Tereshchenko also discussed the vortex models for load calculations on rotor blades. They have modelled non-stationary structure of streamlines for every rotor blade using vortex lattice method. No quantitative findings are however discoursed by them in the paper. Ponta and Jakovkis described the equations convoluted in the calculation of stresses and other parameters of Darrieus wind turbine analysis with Vortex Model. The equation to calculate stresses are simplified to the following form: In the above formulation, '' is the stress induced in the rotor blade, 'k' is the kinematic viscosity '' is the density of air, and is given as the boundary layer thickness. The vortex methods can also be used for the determination of aerodynamic coefficients and measurement of efficiency of the turbine.

IV. CONCLUSION

A Vertical axis wind turbine provides solution for economically sustainable energy in remote areas which are away from the integrated grid system. In order to make them more popular the problems related to poor self-starting and initial torque should be solved. Following points can be concluded form this review. Enough potential to produce wind energy is available in the world. So a proper design of wind turbine would be able to extract the wind energy to electrify the remote areas which would save the cost of transmission. These turbines also have rational playback period. A proper operating range will improve the coefficient of power. With help of modern technology incredible benefits can be offered by this VHWT. Currently available advance technologies have been revived for overall performance. The selection of choice of wind turbine, wind velocity, site height, and wind power potential have to be considered. Before calculating the turbine parameters metrological data is required for maximum efficiency. Blade design plays an important role in the whole system. Higher power can be generated with this vertical axis wind turbine with moderate wind speed if the shape of blade is properly designed.

REFERENCES

[1] *G.M. Joselin Herberta, S. Iniyanb,_, E. Sreevalsanc, S. Rajapandiand* ―A review of wind energy technologies‖; Department of Mechanical Engineering, St. Joseph's College of Engineering, Chennai-119, India

[2] 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 16 (2012) 1926–1939 Department of Mechanical Engineering, University of Engineering and Technology Lahore, G.T. Road, Lahore, Punjab 54890, Pakistan

[3] Young-Tae Lee, Hee-Chang Lim ―Numerical study of the aerodynamic performance of a 500 W Darrieus-type vertical- axis wind turbine, School of Mechanical Engineering, Pusan National University, San 30, Jangjeon- Dong, Geumjeong- Gu, Busan 609-735, South Korea

[4] Bavin Loganathan, Harun Chowdhury, Israt Mustary and Firoz Alam ―An experimental study of a cyclonic vertical axis wind turbine for domestic scale power Generation, School of Aerospace, Mechanical and Manufacturing Engineering, RMIT University, Melbourne, 3083, Australia

[5] K. Pope, I. Dincer, G.F. Naterer ―Energy and exergy efficiency comparison of horizontal and vertical axis wind turbines, Faculty of Engineering and Applied Science, University of Ontario Institute of Technology, 2000 Simcoe Street North, Oshawa, Ontario, Canada

[6] Robert Howell, Ning Qin, Jonathan Edwards, Naveed Durrani ―Wind tunnel and numerical study of a small vertical axis wind turbine‖ Department of Mechanical Engineering, University of Sheffield, Sir Frederick Mappin Building, and Mappin Street, Sheffield, UK

[7] Chaichana T, Chaitep S.―Wind power potential and characteristic analysis of Chiang Mai, Thailand. Mechanical Science and Technology 2010;24:1475–9.

[8] Wilhelm JP, Panther C, Pertl FA, Smith JE. Momentum analytical model of a circulation controlled vertical axis wind turbine. In: ASME 3rd international conference on energy sustainability, vol. 2. 2009. p. 1009–17.

[9] Kopeika OV, Tereshchenko AV. Wind power transforming systems. Journal of Mathematical Sciences2001; 104:1631–4.

[10] Ponta FL, Jacoviks PM. A vortex model for Darrieus turbine using finite element techniques. Renewable Energy 2001;24:1–18.

[11] Ryan McGowan, Kevin Morillas, Akshay Pendharkar, and Mark Pinder. Optimization of a Vertical Axis Micro Wind Turbine for Low Tip Speed Ratio Operation, The Daniel Guggenheim School of Aerospace Engineering Georgia Institute of Technology, Atlanta, GA, 30332, United States

[12] Centre for Wind Energy Technology, Chennai, accessed at http://www.cwet. tn.nic.in/html/information.html (2013)

[13] Source: MNRE accessed at http://bit.ly/14woYJX (2016)

[14] India wind energy outlook 2012, accessed at http://www.gwec.net/wp-content/uploads/2012/11/India-Wind- Energy- Outlook-2012.pdf

[15] Conail Soraghan, Prof. William Leithead, Peter Jamieson, 2013, University of Strathclyde.

[16] David A. Spera, 2012, Models of Lift and Drag Coefficients of Stalled and Unstalled Airfoils in Wind Turbines and Wind Tunnels Jacobs Technology, Inc., Cleveland, Ohio NASA/CR—2008-215434.

[17] Marco Raciti Castelli , Andrea Dal Monte , Marino Quaresimin and Ernesto Benini ―Numerical evaluation of aerodynamic and inertial contributions to Darrieus wind turbine blade deformation‖ DOI: 10.1016/j.renene.2012.07.025