A Review on Vertical Axis Wind Turbine Used for Household Applications

MOHD HASHAM ALI[1], Dr. SYED NAWAZISH MEHDI[2], Dr. M.T. NAIK[3]

[1]Research Scholar, Mechanical Engineering Department, JNTUH & Asst. Prof., MED, MJCET
[2]Supervisor, Mechanical Engineering Department, JNTUH & Prof., MED, MJCET
[3]Co-Supervisor & Professor, Mechanical Engineering Department, JNTUH

Abstract
In this paper an overview of a vertical axis wind turbine is specified. The performance of the Vertical Axis Wind Turbine (VAWT), current scientific status and new result during modeling work and future course of VAWTs were reviewed. It was observed that VAWT plays a critical role in the present power crisis. Wind energy has been recognized as a capable renewable option even though the full life cycle accounting shows VAWTs are profitable on a cost base or materials base over horizontal axis wind turbines (HAWTs), Currently the VAWTs do not generate sufficient electricity owing to some challenges which discussed in this paper. Lift driven VAWT (Darrieus type), Drag driven VAWT (Savonius type) and hybrid of both (D+S) turbine efficiencies can be improved by adding the deflector arrangement that guides the wind towards the turbine blades. At current level a lot of researchers are going on. From the vast survey of the current scientific states of VAWT, it was observed that in India, Tamilnadu provide their place in this research area.

Keywords: *Horizontal Axis Wind Turbine (HAWT), Vertical Axis Wind Turbine (VAWT), Darrieus, Savonius, Renewable Energy Sources (RES), Fossile Fuel power coefficient (Cp).*

1. Introduction

Renewable energy is the newly emerged area in the India at present. It is observed that there is a continues withdrawing of the fossil fuel reserves in the India. Adding to that generation of energy from fossil fuel emits a lot of greenhouse gases, acid rains and global warming which causes environmental issues. Winds, Sunlight, Rain, Tides, Waves…etc are the sources from which the Renewable energy extracted. Electricity generation, water heating and cooling are some of the sources of energy from the wind. Most of the countries have setup 100% renewable energy sources to meet the demand over the power in future Wind energy has been recognized as a promising renewable preference. As wind power has a growing role in energy resources, Many Countries identified and they developed new policies to build up it.

A. Wind

The difference in the atmospheric pressure generates the wind, due to which air particles move from high-pressure area to lower pressure area. During flow of air, molecules are subjected to cause Coriolis effect apart from the equator. The winds are frequently referred according to the path from which the wind blows and its energy. Gusts are the small bursts of high-speed winds. Squalls are the strong winds of intermediate duration..Breeze storm and hurricane are the different Long-lasting winds.

B. Wind control

Electricity generated by wind turbine with the motion of rotor blade by using wind power to impel electric generator. [1] Generator produce electricity and is moved from tower to transformer and controls output voltage of about 700V or more is moved to grid having 33000V and is converted to 240 for household applications.[3] Power of the wind is an unusual and smart source for both small scale , large scale and allocation of power generation applications. Being modular and scalable is one of the important advantages of wind energy. It is likely to seldom get applications in both large wind farms and circulated power generation. The effect of using wind energy, the dependency on fossil fuel also is reduced, people moving advance to speed up the progress of wind technology and additional reduce its costs, to create innovative jobs, and to get better environmental quality. Onshore wind one of the inexpensive source of generating electric power, compared to fossil fuel plants. [5][7][9]. One of the most stronger and stable wind are Offshore winds farms which have less illustration impact, and have high maintenance costs than onshore. [11]

C. Growth of Wind Energy in the World

Globally, there is a quick development in wind power. Due to large technological improvements, industry developments and increasing concerns with greenhouse effects the utilization of wind for electricity generation is increasing rapidly. From the given huge resources, a small portion of the useful wind energy is utilized presently. Electrical industry regulations and Government, plays a major role in adopting wind power so quickly. India have also widely harnessed this energy source. The power generation and the price of wind energy had bring down in UK as it is one of the largest wind energy generations country. Globally installed capacity of wind power is 54GW as stated by the Global wind Energy Council (GWEC) in 2016, and additional 60 GW by 2017 and about 75 GW by 2021, and to increase the growing installed capacity more than 800 GW by 2021 end [13]. Day by day other technologies are also rapidly developing, in spite of wind turbine technology.

D. Wind Turbine

The kinetic energy which extracts from the wind in the wind turbine blades is converted into the mechanical power of the wind turbine as given below.

$$P_{Mech} = \frac{1}{2}\, x\, \dot{m}\, x\, V_i^2 - \frac{1}{2}\, x\, \dot{m}\, x\, V_o^2\ (V_i > V_o) - - - - - 1$$

Where ṁ = Mass flow rate (kg/s),
V_i is inlet velocity (m/s) and Vo is outlet velocity (m/s). [4]

E. TYPES OF WIND TURBINES

Mainly there are two types of wind turbines. They are HAWT and VAWT, HAWT gives more output than VAWT[6]. But, HAWT wants high speed of air velocities to give its utmost performance. According to the wind speed and the directions, the comparative velocity angle of the wind also changes. The relative wind speed becomes more inclined towards the tip, only when the blade velocity increases to the tip. Then causes high noise as it generates tip vortices.

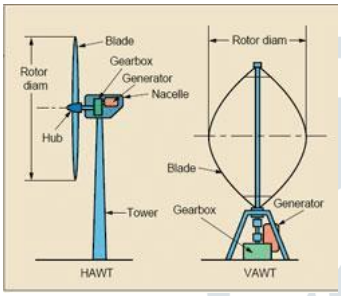

Figure 1: Two main types of wind turbines (Courtesy [21])

The aim of this review paper is to study the performance of the Vertical Axis Wind Turbine, current scientific status and new result during modeling work and future course of VAWTs,

2. Vertical Axis Wind Turbine

VAWTs present numeral advantages over traditional horizontal-axis wind turbines (HAWTs). They are silent, Omni-directional, and they generate lower forces on the support arrangement. They don't need a large amount wind to produce power. When the wind passes from the blades of a HAWT, all of them produce the energy. But in the case of a VAWT, only a portion of the blades produces torque while the other parts just pass through the wind. There by resulting in a reduced efficiency in the generation of power. It is for the reason that of the performance of VAWT is very responsive to the lift/drag ratio of the blade and it is not good in the low Reynolds number condition of small applications. There are a number of challenges in scaling VAWTs to commercial size. The first is that they aren't as well-built by design as a HAWT. This is because of where a HAWT carries most of its stress compared to widely-used VAWT models. VAWT looses definite quantity of wind as they are designed much nearer to the ground than HAWTs. Darrieus type is known to b e lift driven and Savonius type is known to be drag driven. The rotor shaft of the VAWT which is the main part is arranged vertically. By using that shaft a generator is connected. The main attention today is focused on lift driven turbines, as the lift driven turbines gives the maximum efficiency than the drag driven turbines.

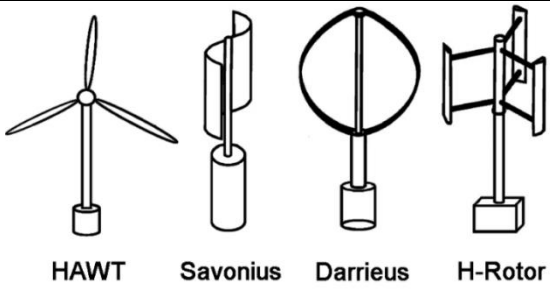

Figure 2: Main types of vertical axis wind turbines (Courtesy [22])

The main disadvantage of the previous designs was major variation of torque during the rotation and there is a huge bending moment on the blades. Consequent projects brought the issue of torque ripple by comprehensive the blades helically. [8] Wind turbine efficiency is measured by using the power co-efficient (Cp). Cp is the ratio of actual power produced by wind to the total wind power at a specific wind speed. [18]

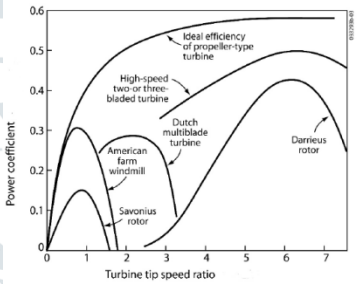

Figure 3: Power coefficient of different VAWTs (Courtesy[24])

From the vast survey of the current scientific states of VAWT, it was observed that in India a lot of research work is going on in the past few years.

A. Darrieus type Vertical Axis Wind Turbine

Aerodynamically blades using NACA standards are used with a certain distance from the rotation axis. [17] As the Wind turbine having high speed and low torque turbine, there are many challenges to protect the Darrieus turbine from those conditions.

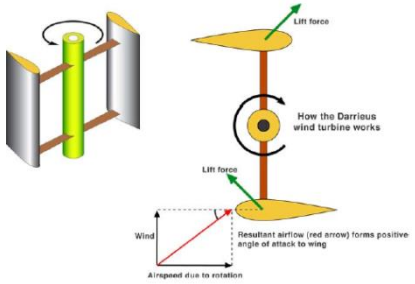

Figure 4: Darrieus wind turbine operating principle (Courtesy[23])

Regardless of the direction in which the wind is blowing, the arrangement is equally valuable. While the Savonius type starts at 1 m/s or lower. Darrieus type requires an electric sustain to start, and its removal rate around 4-5 m/s , To solve the problem of self starting of the Darrieus type turbine a hybrid system is introduced. That arrangement combines the Savonius type which Start at low speeds. Darrieus type has high *(Cp)* than Savonius type. The angle of attack of the turbine blades should not exceed ± 20^0 since it becomes disordered causing halt [19]. Generally the angle of attack controls the lift and drag forces.

A wind turbine can give its maximum performance when lift to drag ratio is maximum and having optimum angle of attack. Airfoil cross sections should be associated with the best possible angle of attack. These are the sections that researchers concentrate on right now [20]. It causes to reduce the downstream air pressure and increase the turbine efficiency. The wind power is proportional to the cubic power of the wind speed approaching a wind turbine. It means that a small change in the acceleration increases a large amount of energy generation. The upstream deflector system generates large size of partition behind it, where a very low-pressure region appears to draw more wind compared to a wind turbine without deflectors. Due to this effect, the coming flow in the deflectors will be efficiently intense and accelerated. Some of the different types of wind turbines are Giromill type, Cycloturbine

Figure 5: Helical Blade Vertical-Axis Wind Turbine [12]

B. Savonius type Vertical Axis Wind Turbine

.It is Savonius type VAWT and it is a drag based VAWT which operates in the same way as a cup anemometer. On the other hand, it has around 15% of wind turbine efficiency. It means only 15% of the wind force arresting the rotor and twisted into a mechanical power. It is greatly a smaller amount which produces by the Darrieus type [14]. The Savonius type will revolve slowly but will generate a high torque. Therefore, for the production of electricity this type is not suitable, for the reason that turbine generators need to be turned into hundreds of RPM to produce high voltages and currents. A gearbox can be used to decrease torque and add to generator RPM.

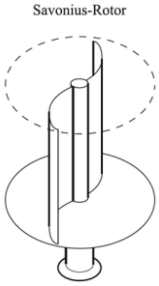

Figure 6: Savonius type Vertical-Axis Wind Turbine (Courtesy[14, 21])

As this type has low efficiency, many researchers are paying attention on the upgrading of turbine efficiency, as it gives much return over other turbines. One of the researchers improved the performance of Savonius type wind turbine by adding up stream wind deflectors. The arrangement of the deflector guides the wind near the turbine blades. [15]

3. Future trends of VAWTs

Many researchers are doing their research in this field, to develop a better VAWT by discovering some parameters like angle of attack, Solidity ratio, lift and drag forces. Ground level is one of the major problems of VAWT as it captures very less amount of air. Using deflector the present problem can be solved by increasing the torque, speed and power which creates an impact over the environment. The performance of turbine can be improved by changing the parameters as mentioned above. NACA and NASA type aerodynamic profile blades are used by the researchers to carry out their research. The efficiency of the turbine can be improved by using self starting NACA blades like NACA 4418 and NACA 4415 [16].

Darrieus type rotor blade has low self starting capacity than Savonius type rotor blade. To overcome this issue a hybrid type i.e. both D+S (Darrieus and Savonius type) rotor blade wind turbine must be installed to get good output. More than 33% to about 42% of performance can be achieved by the blades which are arranged helically when compared with straight blades [17]. Wind and PV hybrid type systems arrangements would be used to get good discharge of the energy when compare individually.

4. Conclusion

Based on the above literature, the performance of VAWT can be improved by the varying some parameters like solidity ratio, lift and drag forces and many more. Many countries are facing energy / power problem and may also face this kind of problem in future due to lack of conventional energy sources. Now the time to shift from NRE sources to RES like Solar, Geothermal, Wind and OTEC (Ocean Thermal Energy Conversation).

If VAWT performance is improved it will be a massive advantage for the establishment of plant all over the countries. CO2 can be reduced if VAWT are implemented at every possible situation and to produce electricity at economical cost. Therefore research over VAWT is acceptable which helps in generation of power and establish the standards of country which gain nations development.

References

[1].Wenehenubun, F., Saputra, A., Sutanto, H., 2015. An experimental study on the performance of Savonius wind turbines related with the number of blades, in: Energy Procedia. Elsevier Ltd, pp. 297–304. doi:10.1016/j.egypro.2015.03.259

[2].M. Young and R. Vilhauer, “Sri Lanka Wind Farm Analysis and Site Selection Assistance”, Global Energy Concepts, LLC Kirkland, Washington, August 2003.

[3].A.A.Wahab, M.F.Abas & N.M.Saad, Ac Voltage Stabilizer For Wind Powered Application In Malaysia, International Symp. & Exhibition on Sustainable Energy & Environ. (ISESEE 2006), Kuala Lumpur, Dec. 2006.

[4].Freude, R. (2017). Physics of Wind Turbines | Energy Fundamentals. [online] Energy-fundamentals.eu. Available at: http://www.energy-fundamentals.eu/15.htm [Accessed 13 Jul. 2017].

[5]. "Wind power is cheapest energy, EU analysis finds". the guardian. Retrieved 15 October 2014.

[6].Performance Simulation of a Small Scale Vertical Axis Wind Turbine (VAWT) with the Integration of a Wind Deflector System. (2014). Undergraduate. Department of Mechanical and Manufacturing Engineering, Faculty of Engineering, University of Ruhuna

[7]. Walwyn, David Richard; Brent, Alan Colin (2015). "Renewable energy gathers steam in South Africa".Renewable and Sustainable Energy Reviews. 41: 390. doi:10.1016/j.rser.2014.08.049.

[8].Raciti Castelli, Marco; Englaro, Alessandro; Benini, Ernesto (2011). "The Darrieus wind turbine: Proposal for a new performance prediction model based on CFD". Energy. 36 (8): 4919–34

[9].Gasch, Robert and Twele, Jochen (ed.) (2013) Windkraftanlagen. Grundlagen, Entwurf, Planung und Betrieb. Springer, Wiesbaden 2013, p. 569 (German).

[10].Claessens, M.C., 2006. The design and testing of airfoils for application in small vertical axis wind turbines.

[11]. Gipe, Paul (1993). "The Wind Industry's Experience with Aesthetic Criticism". *Leonardo*. 26 (3): 243–248

[12].Symscape.com. (2017). Vertical-Axis Wind Turbines | Symscape. [online] Available at: http://www.symscape.com/blog/vertical_axis_wind_turbine [Accessed 15 Jul. 2017].

[13].Myemail.constantcontact.com. (2017). Strong Outlook for Wind Power. [online] Available at: http://myemail.constantcontact.com/Strong-Outlook-for-Wind-Power.html?soid=1102949362881&aid=SM6Rjo6BDjo [Accessed 13 Jul. 2017].

[14].Reuk.co.uk. (2017). Savonius Wind Turbines | REUK.co.uk. [online] Available at: http://www.reuk.co.uk/wordpress/wind/savonius-wind-turbines/ [Accessed 16 Jul. 2017].

[15].Anon, (2017). Performance Simulation of a Savonius Type Vertical Axis Wind Turbine (VAWT) With Wind Deflectors. [online] Available at: http://Performance Simulation of a Savonius Type Vertical Axis Wind Turbine (VAWT) With Wind Deflectors [Accessed 16 Jul. 2017].

[16].Tsai, H.-C., Colonius, T., 2016. Numerical Investigation of Self-Starting Capability of Vertical-Axis Wind Turbines at Low Reynolds Numbers. 34th AIAA Applied Aerodynamics Conference 1–12. doi:10.2514/6.2016-3731

[17].Damota, J., Lamas, I., Couce, A., Rodríguez, J., 2015. Vertical Axis Wind Turbines : Current Technologies and Future Trends, in: International Conference on Renewable Energies and Power Quality (ICREPQ'15) - La Coruña (Spain), 25th to 27th March, 2015. p. 6.

[18].Ftexploring.com. (2017). Wind turbine power coefficient - definition and how it's used. [online] Available at: http://www.ftexploring.com/wind-energy/wind-power-coefficient.htm [Accessed 15 Jul. 2017].

[19].Ragheb, M., 2013. Vertical axis wind turbines. Wind Turbine Technology 40.

[20].Anon, (2017). [online] Available at: https://www.researchgate.net/publication/281405594_Performance_Simulation_of_a_Small_Scale_Vertical_Axis_Wind_Turbine_VAWT_with_the_Integration_of_a_Wind_Deflector_System [Accessed 15 Jul. 2017].

[21] Fouad Ahmed Ahmed, Mahmoud & Abdel Gawad, Ahmed. (2016). Utilization of Wind Energy in Green Buildings.

[22] Kozak, Peter. (2014). Effects of Unsteady Aerodynamics on Vertical-Axis Wind Turbine Performance.

[23] Kumara, E.A.D. & Hettiarachchi, Nandita & Jayathilake, Rukshan. (2017). Review Paper: Overview of the Vertical Axis Wind Turbines. International Journal of Scientific Research and Innovative Technology. 4. 2313-3759.

[24] Kumara, E.A.D. & Hettiarachchi, Nandita & Jayathilake, Rukshan. (2017). Review Paper: Overview of the Vertical Axis Wind Turbines. International Journal of Scientific Research and Innovative Technology. 4. 2313-3759.

[25] E.A.D. Kumara, N.K. Hettiarachchi, K.G.R.M Jayathilake, "Review Paper: Overview of the Vertical Axis Wind Turbines", International Journal of Scientific Research and Innovation Technology (IJSRIT), ISSN: 2313-3759, Vol. 4, No.8, Aug 2017, PP: 56-67.