Overview of the Vertical Axis Wind Turbines

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Abstract

This paper gives an overview of a vertical axis wind turbine. The behaviour of the Vertical Axis Wind Turbine (VAWT), present technological state, new finding through modelling work and future direction of VAWTs were reviewed. It was observed that VAWT plays a vital role in the present energy crisis. Ones can foresee that human being dwelling in a world with wind turbines and solar panels due to present energy crisis with the non-renewable energy. Wind energy has been identified as a promising renewable option

Although the full life cycle accounting shows VAWTs are advantageous on a cost basis or materials basis over horizontal axis wind turbines (HAWTs), Currently the VAWTs do not generate enough electricity due to some challenges which discussed in this paper. Drag driven VAWT (Savonius type), lift driven VAWT (Darrieus type) and hybrid of both (D+S) turbine efficiencies can be increased by adding the deflector system that guides the wind towards the turbine blades. A lot of researches are ongoing at present in thislevel.

From the vast survey of the present technological states of VAWT, it was observed that China is the leading researcher in this field for the past few years while European countries serve their place in this research area.

1. Introduction

The Wind is generated due to pressure difference of atmosphere. Because of the atmospheric pressure difference, air particles move high-pressure end to lower pressure end. During the air flowing, air molecules are subjected to Corioliseffect except exactly on the equator. The winds are often referred to according to the direction from which the wind blows and its force. Small bursts of high-speed winds are called gusts. Strong winds of intermediate duration are called squalls. Long lasting winds have different names such as breeze, gale, storm, and hurricane.[3]

1.1 Wind Power

Wind turbines produce electric power by using the power of wind to drive an electric generator.[4]The generator generates electricity and moves from the tower to an available transformer and switches from the output voltage (usually about 700 V) to a nationwide grid (33000 V) or personal use (about 240 V).[5]Wind power is an attractive and alternative power source for both large scale and small scale and distributed power generation applications. one of the most important advantages of wind energy is being modular and scalable. It is possible to often find applications in both large wind farms and distributed power generation. As a side effect of using wind energy, the dependency on fossil fuel also is reduced.

With largely untapped wind energy resources throughout the world and declining wind energy costs, people moving forward into the 21st century with an aggressive initiative to accelerate the progress of wind technology and further reduce its costs, to create new jobs, and to improve environmental quality.

The onshore wind is an economical source of electric power, competitive than coal or gas plants. [6][7][8]Offshore wind is more stable and strong than onshore, and offshore farms have less visual impact, but construction and maintenance costs are much higher than onshore construction and maintenance. [9]

1.2 Growth of Wind Energy in the World

There is a rapid growth in wind power development globally. This utilization of the wind for electricity generation is expanding quickly, due to large technological improvements, industry maturation and increasing concerns with greenhouse emissions associated with fossil fuel burning. Given the enormous wind resources, only a small portion of the usable wind potential is being utilized presently. Government and electrical industry regulations, as well as government incentives, have a large role in how quickly wind power will be adopted.

European countries have also widely harnessed this energy source. Germany, Denmark and Spain are notable users of wind power. Denmark pushing to generate 40% of its electricity through wind turbines. The UK has the largest wind energy resource and it is set for large expansion to bring down the price of wind energy. The Global Wind Energy Council (GWEC) released the global wind report. More than 54 GW of wind power was installed around the global market in 2016.GWEC's five-year forecast provides for about 60 GW of new wind installations by 2017, reaching an annual market of around 75 GW by 2021, to increase the cumulative installed capacity of more than 800 GW by the end of 2021.[10]

Not only wind turbine technology but also other technologies develop day by day. As an example drones with turbine blades send to the sky and harness wind energy as much as possible and send back that energy through cable. As well as kites use for harness wind energy.

Wind Turbine

Wind turbine blades extract some kinetic energy from the wind and that energy is converted intomechanical power of the wind turbine as below.

$$P_{Mechanical} = 1/2 \times \dot{m} \times V_i^2 \; - 1/2 \times \dot{m} \times V_o^2 (Vi > Vo)$$

Where $\dot{m}$ is the mass flow rate (kg/s), V_i is the upstream wind speed (m/s) and V_o is the downstream wind speed (m/s). [12]

There are two types of wind turbines. They are Horizontal Axis Wind Turbine (HAWT) and Vertical Axis Wind Turbine (VAWT). Normally, Horizontal axis wind turbine (HAWT) gives high power output than Vertical axis wind turbine (VAWT). [13]. But, HAWT needs high speed of air velocities (around Rating speeds) to give its maximum performances. And also, moving wind turbine blade experiences the wind relatively. According to the wind speed and the directions, the relative velocity angle of the wind also changes. As the blade velocity increases to the tip, the relative wind speed becomes more inclined towards the tip. Then generates tip vortices which are caused to high noise.

(a) HAWT (b) VAWT

Figure No. 01 shows the two main type of wind turbines.

The aim of this review paper is to study the behaviour of the Vertical Axis Wind Turbine, present technological state, new finding through modelling work and future direction of VAWTs.

1.3 Vertical Axis Wind Turbine

VAWTs offer a number of advantages over traditional horizontal-axis wind turbines (HAWTs). They can be packed closer together in wind farms, allowing more in a given space. They are quiet, Omni-directional, and they produce lower forces on the support structure. They do not require as much wind to generate power, thus allowing them to be closer to the ground where wind speed is lower. By being closer to the ground they are easily maintained and can be installed on chimneys and similar tall structures. [14]

When the wind passes through the blades of a HAWT, all of them contribute to energy production. When the wind passes through a VAWT, only a fraction of the blades generates torque while the other parts merely 'go along for the ride'. The result is comparably reduced efficiency in power generation. Getting high efficiency from small scale VAWT is somewhat difficult. It is because of the performance of VAWT is very sensitive to the lift/drag ratio of theblade and it is not good in the low Reynolds number condition of small applications. There are a number of obstacles in scaling VAWTs to commercial size. The first is that they aren't as sturdy by design as a HAWT. This is because of where a HAWT carries most of its stress compared to widely-used VAWT models. VAWTs' advantage is only in niche environments. [15] At present, VAWTs don't generate enough electricity that the full-lifecycle accounting shows them to be advantageous on a cost or materials basis over HAWTs. VAWT designs have the blades much closer to the ground than HAWTs, so they are losing significant amounts of wind.[16]

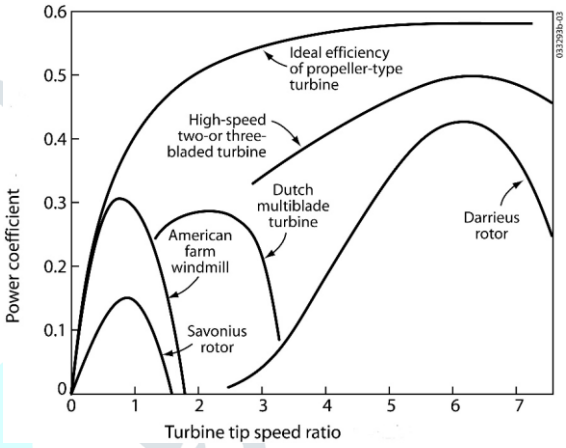
There are two main types of VAWTs called thedrag driven VAWT (Savonius type) and the lift driven VAWT (Darrieus type). The Savonius type functions similar to a water wheel that uses drag forces. On the other hand, the Darrieus type has blades similar to the HAWTs. [15]Main rotor shaft of the VAWT is arranged vertically. The generator can be connected by using that axis shaft. The rudder is unnecessary for this type wind turbines because it accepts the wind which comes from any direction. The maximum possible efficiency of lift driven turbines is larger than the drag driven turbines, the main attention today is focused on lift driven turbines. The first turbine of this design was patented in 1931 by G.J.M. Darrieus. [18]

The main drawbacks of the initial designs were (Savonius, Darrieus and Giromill) significant variation of torque during each rotation and the huge bending moment on the blades. Subsequent projects addressed the issue of torque ripple by sweeping the blades helically. [17]

power coefficient (C_p) is a measurement of the wind turbine efficiency. C_p is the ratio of actual electric power produced by a wind turbine divided by the total wind power into turbine blades at a specific wind speed. [23]Power coefficients of different VAWTs as shown in the below figure.

Fig3 : Power coefficient of VAWT

From the vast survey of the present technological states of VAWT, it was observed that China is the leading researcher in this field for the past few years. Following graph shows that the



interest of research on VAWT in European countries during the year 2010 -2014.

2. Future trends of VAWTs

Although predicting the future, based on the presently available data is not always fully accurate, we can get some idea where the Vertical Axis Wind Turbine technology goes.

A major problem encountered during the operation of VAWTs is low air capture, as it very close to the ground level. The deflector system that guides the wind towards the turbine blades will be solved that problem. It increases the power, speed and torque in these sorts of environments. A lot of researches are ongoing at present in thislevel.

A lot of researchers have developed basic wind turbines, and discover significant parameters that directly involve to changing performances of turbines. Some of them are blade solidity, lift force, drag force and angle of attack. Furthermore, so many researchers have done with considering blade profile. The modern VAWTs occupied blades that developed by NACA which has the ability to self-start. However, researchers are involved

to modify common VAWT and increase its efficiency while global attention on it. Most popular self- starting NACA blades are NACA 4415and NACA4418[34]
Because of the low self-starting capabilities of the Darrieus type turbine, integrate the Savonius type blades by making ahybrid system. This will be very popular use in small generating installations, especially in urban environments that currently have winds that are not exploited.

It has been verified by simulations the helical arrangement of the turbine blades increases the power coefficient in comparison with the straight arrangement of the blades from 33% to 42% under same operation conditions. [22] Lot of researches are ongoing through the modelling work in thiscategory.
The VAWT application of the offshore conditions for the major productions is discarded, but ones can be designed to supply weather buoys and boats, either individually or through a wind / PV hybrid system. [22]

3.Conclusion

Local authorities in Sri Lanka, as well as the foreign authorities, will face, lots of problem in the near future due to lack of non-renewable energy sources. So, they are moving for the renewable energy sources like wind, solar energy, tides, rain, sea waves, geothermal heat…etc.
If we can improve the performance of the Vertical Axis Wind Turbines(VAWTs), it's huge advantage for the authorities. They can implement the VAWTs every possible place and generate the electricity while contributing to the reduction of CO_2 production and economic growth.
Thus, by the researches related to the VAWTs, it is accepted to substantial step forward in this field in the foreseeable future. By introducing there search out comes to the country, it would gain for the national development.

4.References

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