

REVIEW ARTICLE

Vertical Axis Wind Turbine: A Lucid Solution for Global Small Scale Energy Crisis

Pranav Mahale*, Niraj Jangid, Akshay Gite and Tushar D. Patil
Dept. of Mechanical Engineering, University of Pune, SITRC, Nashik, India
mahalepranav93@gmail.com*; +91 7798258958

Abstract

For the overall development of any nation be it the social, economic or technological, electrical power has found itself to be of essence. The majority of the electrical power is found to be generated from the conventional sources of energy. Due to the rapid exhaustion of the conventional fossil fuels there has been widespread power shortage throughout the globe hindering the upward progressive trajectory of developing nations. In order to solve this problem, the tangible option is to focalize on development of renewable sources of energy. From the different available renewable sources of energy, we chose to study the scope of wind energy for solving problems of small scale power generation. Wind Energy is the fastest growing energy resource and most importantly is clean. Keeping in view all the vital factors, low cost wind energy has become a primary solution. Earlier practices used Horizontal axis wind turbine, but to meet the requirements of task, Vertical axis wind turbines were selected for its easy installation, less noise and being environmental friendly. This review is a compiled study of different vertical axis wind power generation alternatives and selecting the most efficient option.

Keywords: Wind energy, vertical axis, horizontal axis, wind turbine, renewable energy.

Introduction

There has been a rapid inflation in population growth, standard of living and industrialization in the past decades. These factors have led to growing demand on electricity and it is surely not expected to decrease any time soon. Traditionally, the electricity demand is satisfied by the primary sources such as the fossil fuel, but its inherent finiteness and environment degradation has necessitate to search for better alternatives. One solution is renewable non-conventional sources of energy. Renewable resources must be researched and developed to steer the global energy supply towards a sustainable path. Sunlight, wind, rain, tides and geothermal are the renewable sources of energy. Renewability is the property of the energy source to not deplete when used either by due to its inherent mass quantity or quick replenishment (Ahmed *et al.*, 2006). Renewable resource is a very wise choice due to its many advantages; they are environmental friendly, inexhaustible and require less maintenance. The only disadvantage being that they require very high capital for installation, though the investment is offset by its low cost of operation. Once the construction is finished, the energy produced is free of cost (Sheikh, 2010). The main focus of our review was on the observation that wind power is the most prolific renewable resource among its counter parts. Wind energy is captured by wind turbines. They convert the wind energy into wind power with the use of electric generator. There are two types of wind turbine: (1) Horizontal axis wind turbine, (2) Vertical axis wind turbine.

Vertical axis wind turbine collect wind from 360°, some with helical blades are capable of running from wind flowing top to bottom (Corbus and Meadors, 2005). Due to its versatility, vertical axis wind turbine are thought to be ideal for installations where winds are inconsistent or where turbines can be placed high enough where there may be steady winds. The urban and sub-urban areas have inconsistent winds, therefore it makes sense to install vertical axis wind turbine there. High density of tall buildings and skyscrapers, make the horizontal wind currents to divert and flow perpendicular to ground surface. The helical VAWT can use this wind current blowing in from any direction (Akhtar *et al.*, 2009) to displace the blades and produce torque in turn generating electricity. Another application where VAWT can be used is the highways having almost constant supply of wind, due to fast moving vehicles (Chantharasenawong and Tipkaew, 2010). The major motivation of this review was to study different available options in VAWT and chose a type which has superior prominence on highways. The electricity demand for lighting and miscellaneous highway activities such as the toll plazas are satisfied by local electricity pool. Installation of VAWT at the median strip of highways will certainly reduce the mentioned dependency making it self-sustainable in the future (Sicot, 2008).

Global energy scenario

Renewable energy use was around 1.7 billion tonnes of oil equivalent in the year 2010, accounting for 13% of global primary energy demand.

With changing contributions of different renewable sources this share has remain constant. Hydroelectric power which is the largest source of renewable energy remained stable. Solar generated power grew by 42% per year during this period, while electricity generated by wind increased by 27%. The renewable sector has not been immune to the recent global economic crisis, but weaker performance in some regions, for example, in parts of Europe and the United States, was largely offset by strong growth in the rest of the world, notably Asia (Biorl, 2012).

Indian energy scenario

In 2010, the Jawaharlal Nehru National Solar Mission was launched being a policy targeting 20 GW of grid-connected solar power by 2022. The plan also covers off-grid solar power, with special attention on rural electrification, solar lighting and heat. The main subsidy mechanisms for solar and wind power are feed-in tariffs. The re-settlement issues have added to uncertainty to the expansion of large hydropower, provided by the five-year plan. The wind power generation department is not working at its full potential as seen from the statistics. India's wind power potential is about 45000 MW, harnessing less than 8% of total potential. The cost per unit of wind energy as compared to the thermal energy has a little marginal discrepancy. It is Rs. 4-4.5 crore/MW for wind energy and Rs. 3.7 crore/MW for thermal energy. When one takes into consideration the environmental toll of thermal energy, wind energy is the more suitable choice. Moreover wind is an omnipresent resource that can be used infinitely, and it can be generated locally.

Wind turbines

A wind turbine basically is an electromechanical device that generates electrical power from the kinetic energy of the wind. Historically they were used frequently as a mechanical device to turn particular machinery. Nowadays, a large quantity of electricity can be generated by these turbines via wind farms both onshore and offshore. As a result of more than a millennium of windmill development, today's wind turbines are manufactured in a wide range of types, which we will be studying. The classification of wind turbine is done on the basis of its axis of rotation. There are of two main types:

- Horizontal axis wind turbine.
- Vertical axis wind turbine.

Horizontal axis wind turbines (HAWT)

As the name suggests, the axis of rotation here is horizontal with respect to the earth or it is roughly parallel to wind current. These have their generator and main rotor shaft at the top of the tower and it is imperative for them to be pointed into the wind. In order to harvest the wind energy, the HAWT are equipped with 'yaw' mechanism to turn the turbine against the wind direction. There are two types of blades used on the turbines, being the drag type and the lift type (Meyers, 2015).

Vertical axis wind turbines (VAWT)

VAWT have their axis of rotation vertical with respect to the ground, roughly perpendicular to the wind stream. These have their main rotor shaft installed vertically. The major benefit of this arrangement is that, the turbine need not be pointed into the wind as in case of HAWT. While the gearbox along with the generator can be placed adjacent to ground, with assistance of direct drive from rotor assembly to ground-based gearbox, making maintenance a less tedious task. The 360° rotation of the blades negates the use of 'yaw' mechanism for harvesting wind energy. VAWT have blades also of two types. They are the lift and drag type. Our review as is focused on VAWT, we are going to further study its subtypes, working and scope for future (Meyers, 2015).

Types of vertical axis wind turbines

Vertical axis wind turbines are classified on the basis of their blade profile. The blades may work on the principle of drag or lift. Below are the types of VAWTs and their description in brief:

- Darrieus
- Savonius
- Giromill

Darrieus: Darrieus in 1931 patented a "Turbine having its shaft transverse to the flow of the current". Being one of the common VAWT, this turbine has been the gateway point for further studies on VAWT to improve efficiency. Darrieus turbine has a swept area of, $A=(2/3)*D^2$. Only two times per revolution, each blade of this turbine sees the maximum lift or torque, therefore, making for a huge torque and power sinusoidal output that is not present in HAWTs. The precaution must be taken to avoid the long VAWT blades to have multiple frequencies of vibration during operation. Darrieus turbine has many problems, first the angle of attack changes as the turbine spins, so the maximum torque by the blade is generated at two points on its cycle i.e. at the front and back of turbine, leading to sinusoidal power cycle complicating the design. Second problem is that the mass concentration of the rotating mechanism is at its periphery rather than at the hub. This tends to an increase in centrifugal stresses on the mechanism, which makes it vital to ensure the design does not fail withstanding the stresses. The most common design has 2-3 blades, while some studies indicate that 2 bladed design has better efficiency. At a height of about 100 m, dia of 60 m and the rated power of estimated 4 MW, the biggest example of Darrieus turbine were built in Quebec Canada in late 80s. The frequent mechanical problems and to ensure endurance the output was reduced to 2.5 MW, but it shut down in 1993 (D'Ambrosio and Medaglia, 2010).

Savonius: Savonius in 1922 initially invented the Savonius turbine, but Bessler first attempted to build the turbine in horizontal orientation at the town of Furstenburg in Germany in 1745.

We know that drag-type VAWT can't rotate faster than the speed of wind Savonius being a drag-type VAWT has this characteristic. Therefore, it has a tip speed ratio of 1 or smaller, making it inappropriate for electricity generation. It also has a low efficiency making applicable for pedestrian task such as of pumping water or grinding. Moreover being near to the ground, large part of its swept area receives lower wind speed making energy extraction less effective. Savonius turbines have inherent simplicity and reliability, also produce low noise levels. It can operate at low wind speeds too as torque is high enough at this condition. However the torque not being constant calls for a modification like helical shape blades. They are often used in deep water buoys or in advertisement hoardings. Most of the anemometers are a miniature version of Savonius turbine (D'Ambrosio and Medaglia, 2010).

Giromill: Giromill vertical axis wind turbine was developed by Darrieus in 1927, its straight bladed wind turbine. In Giromill the 'egg-beater' like blades of Darrieus are replaced with straight vertical blades attached to a central hub with horizontal supports. The blade designs assists in making the design simpler, easy to build, but this gives a massive structure as a result. The generator is located at the bottom of tower, thereby easing restrictions on its size and weight. While it is cheaper and simple to construct than its counterparts, they are less efficient working well in turbulent winds. The operational working of Giromill is quite similar to that of Darrieus turbine. Here also the wind strikes the blades and its velocity is divided in two drag and lift component. The turbine's rotation results due the vector addition of these two components. Its swept area is equivalent to product of the blade length and the rotor dia (D'Ambrosio and Medaglia, 2010).

Gorlov helical wind turbine

The three main types of VAWTs have their varied advantages, each work on their respective principle. Taking into account their design and working, we come across certain limitations. A large portion of the limitations are conducive to solve via 'Helical Blade' design implementation. Rather than being a type of VAWT, helical blade turbine is found to be a modification or an evolution in order to adapt to better efficiency. The first of its kind helical blade design was developed by Professor Gorlov of the Boston's Northeastern University. Thus it is named to be 'Gorlov helical wind turbine'. Nowadays, the helical rotor has become the popular choice of inventors of the new VAWT. Designed initially for use in hydro and tidal applications, the design has evolved for usage in wind energy generation application (Gorlov, 1995). One example of it is the 'Quiet revolution' wind turbine. It has the inherent tendency to integrate into present structures due to its modern design of rotor, blades and compactness. The VAWT may be ground or roof mounted. The helical blade design modification is been observed to reduce or

even eliminate the torque ripple seen in the conventional VAWTs mentioned above. Along with its ergonomical perks it has a marvellous aesthetic appeal, the helical rotor is been used by architects to add an essence to their projects. The helical turbine design consists of design of shaft, flange, spoke and blade etc. The turbine shaft material selection depends upon its availability and weight. Steel and Aluminium are the likely contenders for the shaft material. Aluminium is largely preferred but availability is the main issue, otherwise the heavier steel is selected. The spoke arms are attached to the shaft with the assistance of the flange, machined out of preferably aluminium. The flanges may be designed in separate pieces instead of in unison with the spoke arm to reduce the material required. The flanges are then attached to the spoke arm with bolts and a single threaded hole for a set screw to secure them. The spoke arm component has three arms extending from the central hub of the part with extend sections at the end of the arms to attach the turbine blades. Quarter-inch polycarbonate is an ideal material which can be machined using a CNC machine. The most important part, turbine blades are produced using 3D printer that built the blades up a layer at a time. The blade profile maybe air foil in nature. Due to size constraints of the printer, the blades have to be cut in half and then assembled and this combination maybe done with mixture of plastic cement and pins to strengthen the joint.

Conclusion

The implementation of vertical axis wind turbine would greatly benefit the non-conventional energy resources ministry. It would also reduce the burden on the usage of conventional energy sources. They can be installed on highway's median strip, with width being the only constraint. These turbines are comparatively easy to build and the investment is also well affordable when compared to the HAWTs. Since the turbines are smaller in size, they can be only used for low power applications such as for powering streetlights or the toll plazas. Moreover, they may also be used to power the advertisement hoardings. Future prospect, the addition of speed governing system and control circuit may make the model much acceptable. The emerging trends in the technology have shown a way to the use of non-conventional energy sources so efficiently and a little effort at the side may find an effective solution for the boom of the electrical energy by the society. Conclusively, extensive data is collected on wind patterns produced by vehicles on both sides of the highway. Using the collected data, a wind turbine is designed to be placed on the medians of the highway. Although one turbine may not provide adequate power generation, a collective of turbines on a long strip of highway has potential to generate a large amount of energy that can be used to power streetlights, other public amenities or even generate profits by selling the power back to the grid.

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