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Comparative Study of Different Types of Wind Turbine and an Overview of Some Issues Related with Wind Energy

[1]Sagar P Patil[#], [2]Abhijit R Deshpande[*], [3]Kirankumar R Jagtap[#]
[#]*Department of Mechanical Engineering, SITS, Pune, India 411041*
[1]*patil.sagar8791@gmail.com*
[3]*kirankumarjagtap@sinhgad.edu*
[*]*Department of Mechanical Engineering, VIIT, Pune, India, 411048*
[2]*abhijitdeshpande32@gmail.com*

ABSTRACT: *As energy demand around the world is increasing day-by-day, wind energy is the good option for energy generation. The most common type of wind turbine is horizontal axis wind turbine (HAWT), but there exist other types. In this paper four different wind turbines are considered, three vertical axis wind turbines (VAWT): the Savonious, the Darrieus, the Giromill or H-rotor; and the HAWT. This study deals with the comparative study of these four different types of wind turbines from the most important aspects including design, construction, maintenance, blade profile. In this study it has been found that VAWT is more advantageous over HAWT in several aspects. Furthermore, different economic, environmental, technical and social issues related with wind energy are discussed.*

Keywords*— Darrieus, Giromill, HAWT, H-rotor, Savonious, VAWT.*

I. INTRODUCTION

Wind results from air in motion. As energy demand around the world is increasing day by day, Wind energy is the one option for fulfil the needs. As compared to other renewable energy resources like solar energy, hydro power, geothermal, wind energy has economic, social and environmental benefits. The total kinetic energy of the wind in the lowest kilometre, if harnessed, can satisfy several times the energy demand of a country. Wind energy is clean energy that produces zero emissions i.e. it does not responsible for any global climatic changes like smog, acid rain, snow formation, mercury contamination. Wind energy is cost competitive to other sources and wind energy systems have low operating cost. Also wind energy creates employment.

Wind Turbine is a device used to convert the kinetic energy, also known as wind energy, available in wind into mechanical energy.

II. HISTORY

The First energy source used by human beings is wind. Sails were used on boats as early as 5000 BC. Windmills first appeared in Europe during the middle age. In 900AD, Persians made first vertical axis type windmill and that was used for pumping the water, grinding grain, etc. [1, 2]. Scottish academic James Blyth made first electricity generating wind turbine in July 1887 and that was battery charging machine. But the first automatically operated wind turbine was built by American Scientist Charles F Brush in 1888 for electricity production.

III. CLASSIFICATION OF WIND TURBINE

The Wind turbines are classified on the basis of different ways. Following are the main criteria's to classify the wind turbines:

A. On The Basis of Amount of Electrical Power Output [1, 4]

1) Small Size Turbines: These wind turbines produces electrical power output up to 2 kW. These turbines may be used for low power applications or at remote places.

2) Medium Size Turbines: These wind turbines produces electrical power output in the range of 2 kW to 100 kW. These turbines are used for residential or for local use.

3) Large Size Turbines: These wind turbines produces electrical power output more than 100 kW. These turbines are used to generate power for distribution in central power grid.

B. On The Basis of Rotor Axis Orientation [1, 4]

According to this criteria wind turbines are classified into two main categories, namely horizontal axis wind turbine (HAWT) and vertical axis wind turbine (VAWT).

1) Horizontal Axis Wind Turbine: A HAWT is the most common wind turbine design. In this type, the axis of rotor is parallel to wind direction. In another words, axis of turbine is parallel to ground. According to the number of blades, these are again classified into single bladed, double bladed, three bladed, multi-bladed and bicycle bladed.

2) Vertical Axis Wind Turbine: In this type, the axis of rotor is perpendicular to the direction of wind, i.e. perpendicular to ground. These turbines are also called as cross-wind axis turbine. They are again broadly classified into Savonious and Darrieus type turbines.

C. On The Basis of Type of Power Output [1, 3]

1) DC output: This type of wind turbines includes DC generator and alternator rectifier.

2) AC output: This type of wind turbine includes Variable frequency, variable or constant voltage AC and constant frequency, variable or constant voltage AC

I. COMPARISON BETWEEN DIFFERENT TYPES OF WIND TURBINES

The wind turbines considered here for comparison are Horizontal Axis Wind Turbine and three types of Vertical Axis Wind Turbine; Savonious Type, Darrieus Type and H-Rotor or Giromill Type.

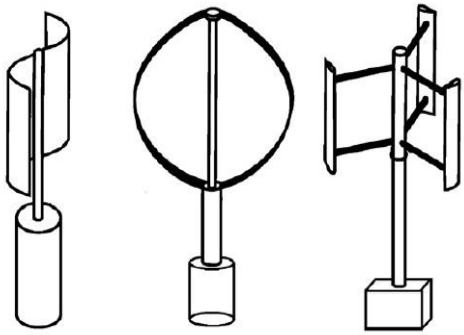

Fig. 1 To the left is a Savonious; in the middle a Darrieus and to the right an H-rotor

A. Tower Structure

The HAWTs are mounted on tower and there are wind forces on the tower. Both upwind and downwind locations have been used so that tower design is an essential aspect of the overall system design. Darrieus type VAWTs are mounted on the ground eliminating tower structure and lifting of huge weight of machine assembly, i.e. it can be operated close to the ground level [2].

As compared to all three types of VAWTs, HAWTs require massive structure which is very costly [1].

B. Yaw Mechanism

The main difference between all type of VAWT'S and HAWT is the VAWT'S are Omni-directional i.e. they can accept wind from all directions. The HAWT'S are required to be pointed into wind because they can accept wind from one direction only. So they require Yaw mechanism which changes position according to the wind direction and adjust the blades. The Yaw mechanism is very costly because it includes the cost of mechanism itself, installation cost, operational cost and maintenance cost. It may fail during operation of turbine.

C. Cost

The cost of wind turbine includes the manufacturing cost of total setup, the cost for site preparation, the installation cost of wind turbine and other components like gearbox, generator, cables, etc. and maintenance cost. The cost of wind turbine is measured in terms of cost per generated energy i.e. cost/kWh [6]. According to Walters et al. analysis, VAWT's are quite cost effective than HAWT [9].

D. Construction

The manufacturing of blades is easier for H-rotor type VAWT than other types. The manufacturing process of Darrieus type turbine is more complicated because they have curved blade which are very difficult to fabricate

and transport. For same power capacity, the length of blades of H-rotor type is more than that of HAWT for which more material is used.

E. Performance:

The power coefficient C_P is used to measure the performance of wind turbine. Coefficient of power states that how efficiently the wind turbine converts the energy in the wind into electricity. C_P value is unique to each turbine. According to German Physicist Albert Betz, no wind turbine can convert more than 16/27 i.e. 0.593 or 59.3% of the kinetic energy of the wind into mechanical energy turning a rotor.

For HAWT, the value of Coefficient of power is usually between 0.40 and 0.50. For VAWT, the C_P values are depending on theoretical studies and on experimental results from different studies and are around 0.40 [2].

II. ECONOMICS OF WIND ENERGY

The cost of electricity produced per unit is highly dependent on local wind regime. The power output from any wind turbine is proportional to cube of the wind speed. So a slight increase in wind speed will mean a significant increase in power output subsequent decrease in per unit cost [6]. The cost of wind turbine includes the manufacturing cost of total setup, the cost for site preparation, the installation cost of wind turbine and other components like gearbox, generator, cables, etc. and maintenance cost. The cost of wind turbine is measured in terms of cost per generated energy i.e. cost/kWh.

Fig. 1 shows the pictorial view of different types of wind turbines. The comparison of different types od wind turbine is summarised in Table 1.

IV. IMPORTANT ISSUES RELATED WITH WIND ENERGY

A. Environmental and Social Issues

Wind power is a clean renewable energy source. However, there are some considerations to keep in mind when planning a wind energy plant. They include following,

1) Noise: The noise level s from large, modern wind turbines are relatively small, consisting of low pitch rhythmic "Whooshing" sound. Wind rotors, generators and gearboxes create acoustic noise when functioning [7]. "Wind-farm syndrome" is a term used to describe a variety of health maladies caused by inaudible "infrasound", but the scientific backing for this is minimal.

2) Wildlife: The large, rotating blades of rotor cause hazard to birds and bats. The main complaint against

Parameter	**Type of Turbine**			
	HAWT	**Savonious**	**Darrieus**	**Giromill**
Tower Structure	Needed and Complicated	Not Needed	Not Needed	Not Needed
Blade Construction	Complicated	Moderate	Complicated	Simple
Yaw Mechanism	Needed	Not Needed	Not Needed	Not Needed
Guy Wires	No	Optional	Yes	No
Self-Starting	Yes	No	No	No
Noise	High	Low	Moderate	Low
Gear Box and Generator position	On top of tower	On Ground	On Ground	On Ground
Blade Area	Small	Moderate	Large	Moderate
Foundation	Extensive	Moderate	Simple	Moderate
Overall Structure	Complicated	Simple	Moderate	Simple

installation of wind turbine is danger to birds and bats. A Spanish study estimated that a single wind turbine kills, on average, 10 birds per year. But compared to other manmade hazards, wind turbine represents minor hazard [1, 8].

3) Land Use: As wind power is not a concentrated form of energy, like oil or coal, it requires large amounts of land, typically 10 to 30 acres per turbine. However, most of the land associated with wind farms is "empty space", and could be available for other purposes, such as agriculture.

4) Visual Impact: Medium and large wind turbines sit atop towers 100 ft. high with rotors that can be hundreds of feet in diameter. So, they have significant visual impact on their surroundings. Some argue that it is a positive visual impact [1].

5) Employment: Wind energy development creates thousands of long-term, high-paying jobs in field such as wind turbine component manufacturing, construction and installation, maintenance and operations, legal and marketing services, transportation and logistical services, and more.

B. Technical Issues

Despite the maturity of modern wind technologies, two key technical issues must be addressed before it can find widespread use

1) Variability: Unlike coal or oil power plants, wind turbines don't produce power continuously due to the variability of wind. During periods of low winds, the turbines may be idle, and as a result, there is continuing debate over whether wind power can really reduce the need for conventional power plants. In addition, the wind is rarely steady, leading to short term variability and "noisy" power output [1].

2) Grid Connectivity: The best wind resources tend to be far from the transmission lines ended to connect the wind turbines to the grid. The variability of the power from wind also presents challenges for the current electrical grid system, which was designed for the relatively uniform and predictable power generated from which conventional oil and power plants.

3) Electromagnetic Interference: Interference with TV and other electromagnetic communication systems is a possibility with wind turbines as it is with other tall structures. TV interference is most likely in areas where there is weak signal. Interference can be overcome by dispensing with aerials and sending TV signals by cables.

4) Risk: The possibility of mishap of greater concern to the public. The most serious failure from the safety point of view is the detachment of blade, or blade fragment. A reliable control system to identify the fault situation rapidly and breaking system to bring the rotor safety to rest could be the measure adopted to prevent such failures.

V. CONCLUSION

In this paper, important differences between wind turbines depending on the direction of their axis of rotation have been discussed. According to this study, Vertical Axis Wind Turbines are more advantageous to Horizontal Axis Wind Turbines in many aspects. Again, when comparing the three types of Vertical Axis Wind Turbines considered here, the H-rotor or Giromill type VAWT seems more advantageous over Darrieus and Savonious type wind turbines.

Also, an attempt has been made to discuss number of important issues related to wind energy i. e. classification, environmental aspects, social problems, technical problems, etc.

Today, wind energy provides competitive electricity. Tomorrow, it is likely to be the cheapest source of electricity for the distributed generation of hydrogen. Along with concern over debilitating illness associated with air pollutants, wind energy has over whelming public support.

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