Review of Curved Bladed Vertical Axis Wind Turbine

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ABSTRACT

This paper presents the study and literature survey of curved bladed vertical axis wind turbine. Wind energy is an important form renewal source of energy. Wind energy is the clean source of energy. Here our focus to study of the history of vertical axis wind turbine and basic study of the various types of airfoil used for wind turbine blade. This paper also presents the conceptual study of the terms used in basic wind turbine design.

Keyword: - *Wind Energy1, vertical axis wind turbine 2, Renewal Energy 3, and Clean Energy*

1. Introduction

For a VAWT the blades perform the main role to extract energy from the wind. Curved blade is considered as the blade for this new design of VAWT. Airfoil has some good aerodynamic characteristics, match with the characteristics of Savonius type VAWT, such as good stall characteristics and little roughness effect, relatively high drag and low lift coefficient.

Wind energy is a one of largest renewable energy source. Global wind power potential is of around the order of 11,000 GW. It is near about five times the global installed power generation capacity. This excludes offshore potential as it is yet to be properly estimated.

About 25,000 MW is the global installed wind energy producing capacity. It is about 1% of global installed power generation capacity. Wind produces about 50 billion Kwh per year globally with the average utilization factor of 2000 hours per year. Global wind power growth trends from 1980 to 1995 are shown in Figure 1.

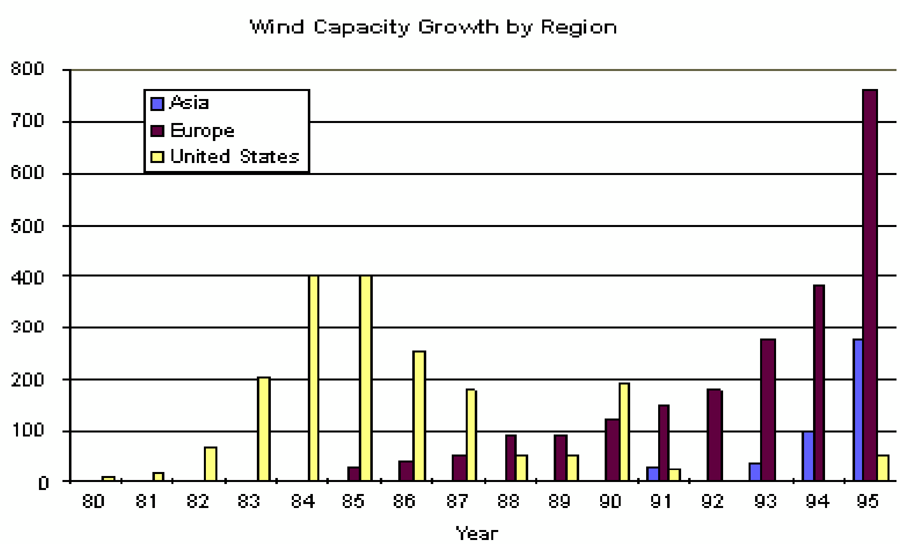

Fig-1: Global wind power growth trends from 1980 to 1995

India's ranking is fifths position in world based on the installed wind power producing capacity. India is producing around 2 billion kWh per year from wind with the average utilization factor of 1175 hours per year. Cost of energy from wind is about Rs.4 to 5 per kWh in India. India has also started exporting 1 MW capacity machines.
Data are available about its availability pattern around the day for different months of the year.

1.1 Wind Machine: The machine that converts kinetic energy in the wind into usable form of mechanical energy (usually shaft power)

Table 1: Different types of Wind Machines

Type of Machine	No. of Blades	Axis of Rotation	Rotor Position w.r.t .Tower	Starting Torque	Rotor Speed	Power
Propeller machine	2 or 3	Horizontal	Upwind or downwind	Moderate	Fast	Electrical
Multi-bladed machine	6 to 24	Horizontal	Upwind	High	Slow	Mechanical
Savonius machine	2 or 3	Vertical	-	Very high	Slow	Mechanical
Darrius machine	2 or 3	Vertical	-	Very low	Fast	Electrical

Study of wind machines is called **Molinology**. It cuts across various fields including Meteorology, Aerodynamics, Machine Design, Structural Design, Materials Technology, Power Engineering, Reliability Engineering, Instrumentation and Controls Engineering.

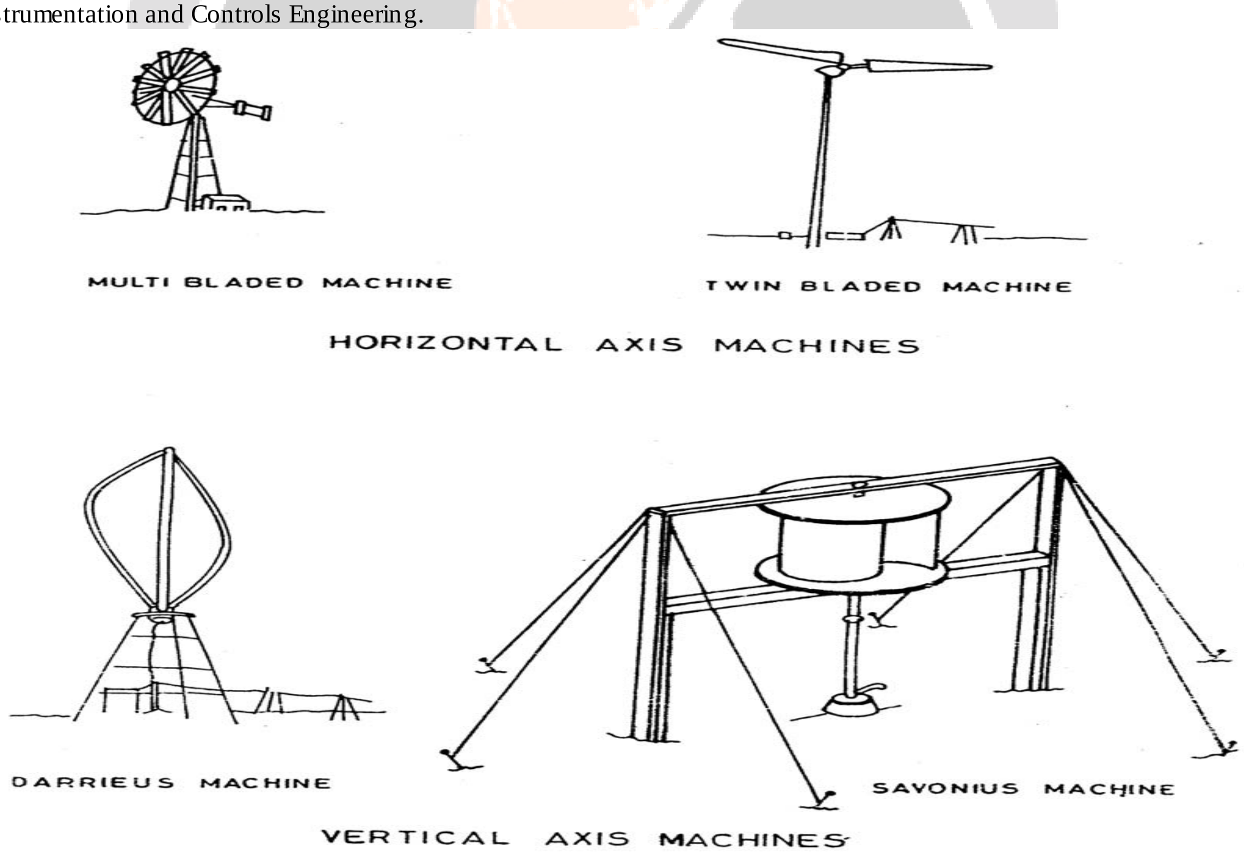

Fig-2: Typical wind machine designs

2. Historical aspects

Some achievements in the history of wind power producing machine detail are given in Table 2. Later on knowledge of depth in fluid mechanics and understanding of aerodynamic shape and position of center of forces or zero moment reduced the structural problem for supporting the blade.

Table -2: Historical development of Wind Energy Conversion System

Period	**Machine**	**Application**
640 AD	Persian wind mills	Grinding, etc
Before 1200 AD	Chinese sail type wind mill	Grinding, water pumping, etc
12th century AD	Dutch wind mills	Grinding, water pumping, etc.
1700 AD	Dutch w/mill to America	
1850 to 1930 AD	American Multi-bladed	Water pumping, 35 VDC power
1888 AD	Brush wind turbine; Dia.17m, Tower 18.3m	12 kW Electric power
1925 AD	Jacob's 3 bladed propeller Dia.5m, 10-20m/h, 125 to 225 rpm	0.8 to 2.5 kW at 32 VDC
1931 AD	Yalta Propeller, Russia; 2 bladed, dia.100 ft	100 kW
1941 AD	Smith-Putnam Propeller 2 bladed, dia.175ft, 30 m/h, 28 rpm	1250 kW
1925 AD	Savonius Machine	Mechanical or Electrical power
1931 AD	Darrius	Electrical power
1980s AD	2 bladed propeller (Commercially available)	225 kW
2000 AD	HAWT, VAWT	400-625kW, 1.2-3.2 MW

3. Wind machine parameters

Power producing capacity of wind machine is mainly affected by wind velocity, u, swept area by the rotor, AS, air density , ρ, rotational speed of the machine, Ω, rotor radius, R, number of blades, B and total blade area. It is also affected by lift and drag characteristics of the blade profile. Lift and drag forces acting on a blade element is shown in Figure 3Application of dimensional analysis evolves following parameters for characterizing wind machines.

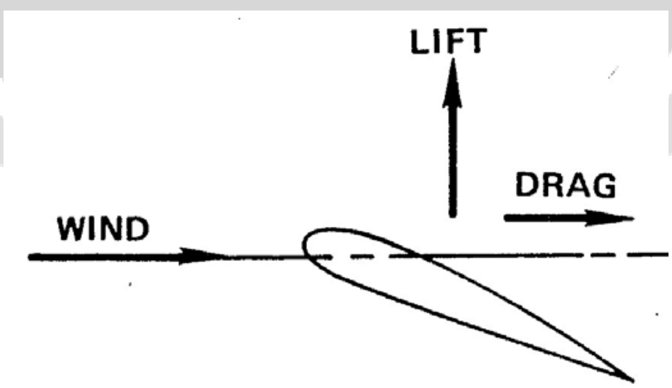

Fig-3: Lift and drag forces acting on a blade element

3.1 Coefficient of Performance, $CP = P / (½ \rho AS u^3)$ Where, P = Power output at rotor shaft (W) AS = Area swept by the machine (m2) ρ = Air density (kg/m^3) u = Undisturbed wind speed (m/s)

3.2 Tip speed ratio, $\lambda = R \Omega / u$

R = Rotor radius (m), Ω = rotational speed of the rotor (rad/s).

3.3 Solidity, σ = blade area / AS = (average chord x blade length x number of blades) / AS.

3.4 Energy content of the wind

The quantity (½ ρ AS u^3) in the denominator of the definition of CP may be identified as power in the wind. It is proportional to the cube of wind speed, u as the volume of bottle is to its dimensions. If u = 15 km/h, power in the wind is 42 W/m^2. For u = 36 and 90 km/h, it is 583 and 9102 W/m^2.

3.4 Drag translator device.

A drag translator is a device which is subjected to wind with speed U and utilizes the drag force of the wind force acting on it to develop the power. Suppose the device is moving at speed v under the wind forces acting on it.

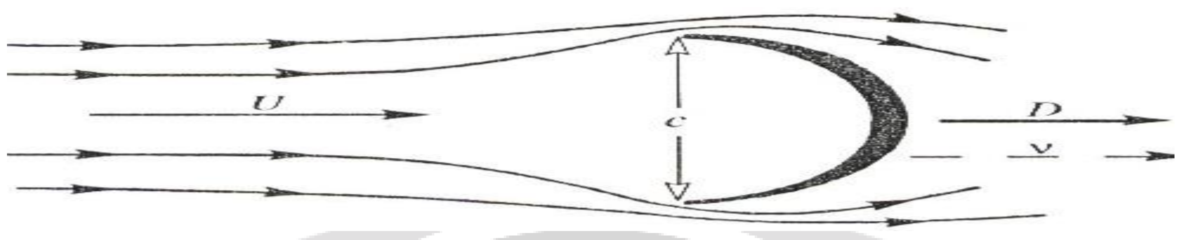

Fig-4: A drag translator device

Then, the relative speed of the wind as seen by the device is (U – v) and the drag force of the wind acting on a unit length of the drag translator device is given by,

D = CD (½ ρ c $(U\text{-}v)^2$)

Where, CD = drag coefficient of the drag translator device c = width or chord of the drag translator device.

3.5 Lift translator device

Lift translator is subjected to wind at speed U. This is a device that primarily utilizes the lift force of the wind acting on it. Let the device be moving at speed v under the wind forces acting on it in the direction perpendicular of the wind.

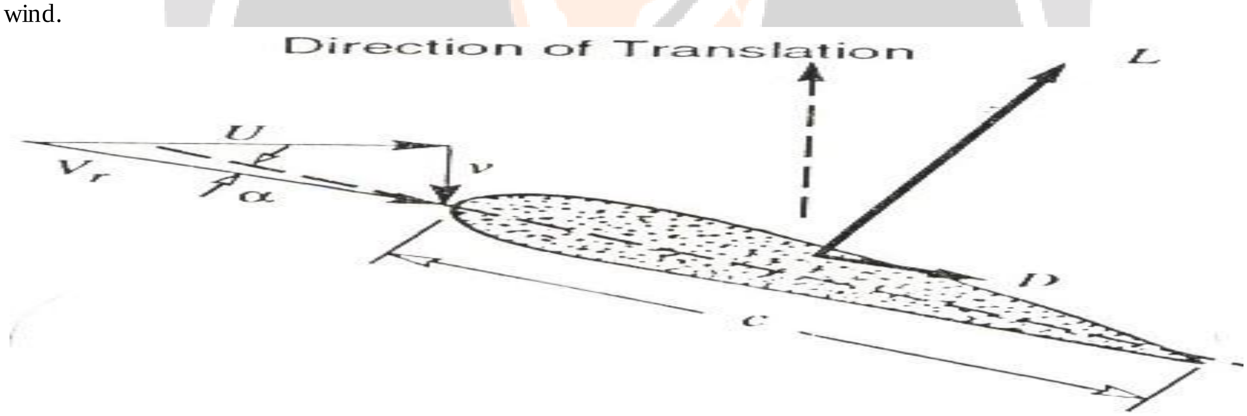

Fig-7: A lift translator device

Let the chord of the device be inclined at angle θ with to the direction of the wind. Then, the relative speed of the wind as seen by the device is Vr = √ (U^2 + v^2) and the driving force of the wind acting on a unit length of lift translator device is given by.

$$F = L \cos \theta - D \sin \theta$$
$$= (½ \rho c Vr^2) [CL\cos \theta - CD\sin \theta]$$

CL = lift coefficient of the lift translator device CD = drag coefficient of the lift translator device c = width or chord of the lift translator device.

3.6 Airfoil section

Airfoil is profiled to have very small drag. A typical airfoil having 200 mm chord and 15% thickness has drag equivalent to a wire of 1mm diameter. It is characterized by coefficient of lift, C_L and coefficient of drag, C_D that are function of angle of attack.

$C_L = L / (½ \rho A u^2)$; $C_D = D / (½ \rho A u^2)$

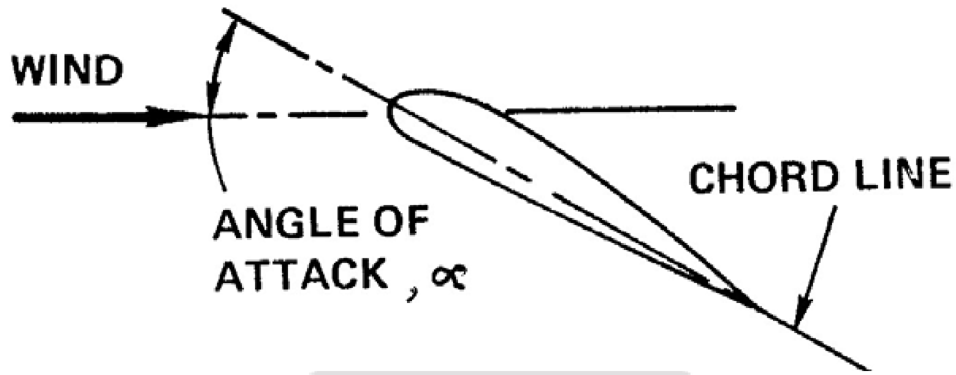

Fig-6: Definition of chord and angle of attack for an airfoil section

Different types of airfoil sections are shown in Figure 12a and typical lift and drag characteristics are shown in Figure 12b. Value of C_L can go as high as 1.2 after which an airfoil stalls, typically at the angle of attack 15^0. Minimum value of C_D / C_L is typically in the range of 0.01 to 0.1.

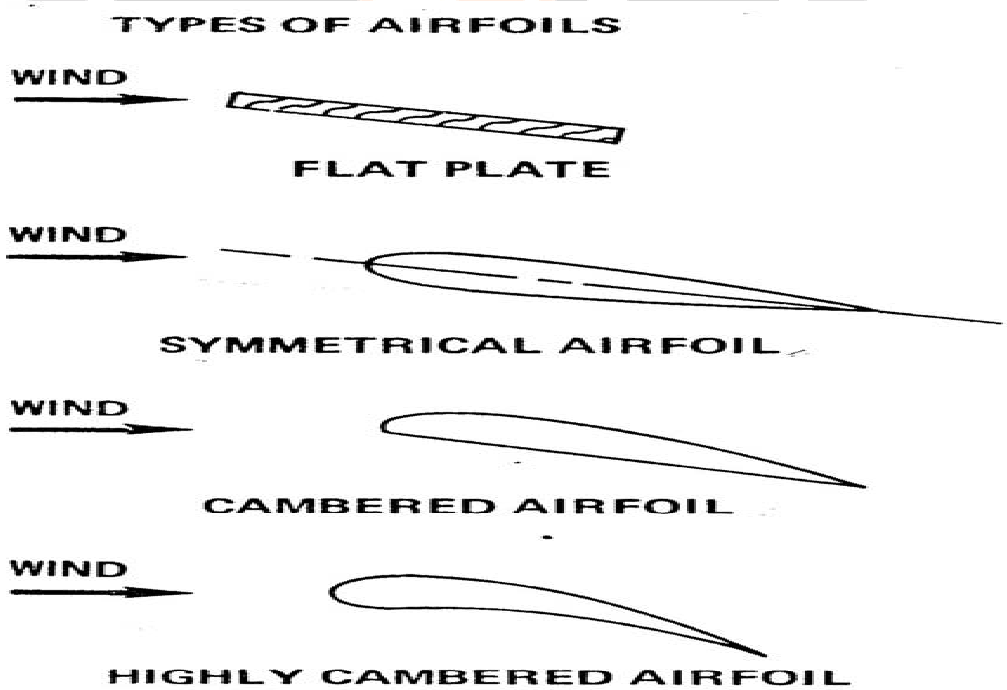

Fig-7: Types of airfoil used on curved blade

4. Literature Survey

4.1 (Price T.J. 2009) [3] State that wind mills were used in Persia in 200 B.C. The purpose of wind turbine for many centuries ago is used for pumping water. The Netherlands used wind mills for dewatering large areas from the 13th century. The ending of the nineteenth century divided the two development periods; the earlier is known as ancient development period and later as the modern development period. In July 1887, Scottish academic James Blyth installed the first electricity-generating multi bladed HAWT to charge his battery for holiday light in Scotland. By 1900, there were about 2500 windmills almost produced 30 MW of electricity for mechanical loads such as pumps and mills in Denmark. By 1908 there were 72 wind-driven electric generators from 5 kW to 25 kW and by 1930 wind farms for electricity were common in USA.

4.2 (Shepherd D.G.1990) [2]was found that about 1300 A.D a Syrian cosmographer Al-Dimashqi drew a vertical axis windmill it was a two storied wall structure with milestones at the top and a rotor at the bottom. It had latter with spooked reel with 6 to 12 upright ribs that covered with cloth. It was found that this type of windmill had been in operation in 1963 which used to produce an estimated 75 hp (at efficiency of 50% at wind speed 30 m/s). Each windmill milled one ton of grain per day (Wulff 1966) [1].

4.3 (S. J. Savonius 1931) [5] The Savonius wind turbine was first used by a Finnish Engineer S. J. Savonius in 1931 (Savonius 1931). The design of his rotor was S-shaped with two semi-circular buckets with small overlap. At that time this rotor was successfully used as an ocean current meter. In 1931, G. J. M. Darrieus in France patented another VAWT named Darrieus vertical axis rotor. This type of rotor was not self-starting.

(Gupta, Das, et al. 2012)[6]The performance of two bladed Savonius turbine with five overlaps of 16.2%, 20%, 25%, 30% & 35% were investigated. Among them 16.2% overlap condition showed maximum power extraction. The pressure drop across the rotor from upstream to downstream as well as, maximum pressure difference across the returning bucket was displayed in the same condition which eventually indicated the better overall aerodynamic torque and power.

4.4 (Carrigan, et al. 2012) [7] had the objective to introduce and demonstrate a fully automated process for optimizing the air foil cross-section of a VAWT. The objective was to maximize the torque while enforcing typical wind turbine design constraints such as tip speed ratio, solidity, and blade profile. This work successfully demonstrated a fully automated process for optimizing the air foil cross-section of a VAWT. As this experiment was not an extensive study, so they had suggested further research and development.

4.5 (M. Rahman, K. N. Morshed, et al. 2009) [8] experimented on the Drag and Torque characteristics of three bladed Savonius Wind Turbine. The turbine with no overlap has better drag and torque characteristics. They also performed Aerodynamic performance analysis on three bladed Savonius wind turbine and concluded that higher reynold number showed better aerodynamic behavior for no overlapping blades.

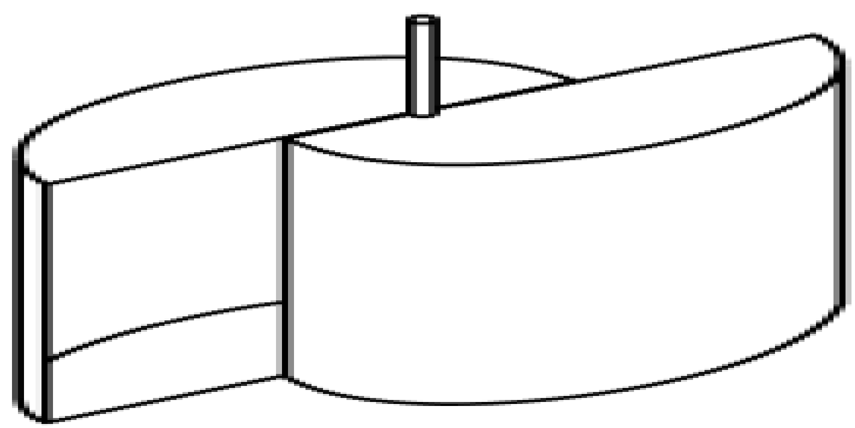

Fig-8: Schematic drawing of a two-scoop Savonius turbine

5. Conclusion

Wind energy is permanent environmentally clean source of energy. This paper shows the study of Curved Bladed Vertical Axis Wind Turbine would look like an "S" shape in cross section. Because of the curvature, the scoops experience less drag when moving against the wind than when moving with the wind. The differential drag causes the Savonius turbine to spin. Because they are drag-type devices, Savonius turbines extract much less of the wind's power than other similarly-sized lift-type turbines. Much of the swept area of a Savonius rotor may be near the ground, if it has a small mount without an extended post, making the overall energy extraction less effective due to the lower wind speeds found at lower heights.

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