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Wind Mill Blade Design-A Review

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Abstract- *Wind power is one of the quickest developing environmentally friendly source of energy. Wind energy is an excellent renewable alternative to reduce the consumption of nonrenewable fossil fuels, such as coal, oil, and natural gas and is the cheapest source of electrical energy. Wind is a type of solar energy that occurs as a result of the sun's uneven heating of the air, the earth's rotation and its surface irregularities. It is available around the clock, is a clean source of energy and require little maintenance. Wind turbines have the potential to provide power to isolated areas and have low operating cost. Wind power means converting kinetic energy into mechanical energy of the blades and converting that mechanical energy into electrical energy by the generator. The paper describes ways to maximize the efficiency of the wind turbines so as to improve the effectiveness of them.*

Keywords: **Horizontal Axis Wind Turbine, Vertical Axis Wind Turbine, Optimum Tip Speed Ratio, Tip Speed Ratio, Blade Element Moment, Buoyant Air Turbine**

1)INTRODUCTION

Even though there are many advantages, there are also many challenges for wind energy. Wind generation must still contest with conventional sources on a price basis. The land which is available for wind-turbine installation must compete with other uses such as agriculture, transportation and infrastructure. To overcome these challenges, the efficiency of the wind turbine must be increased to satisfy the requirements of the people. We need to maximize the viability of the wind energy.The top wind power production country is China followed by USA Germany, India and Spain. Wind energy accounts for about ten percentage of the total power production in India.

Windmill blade design is one of the most important considerations in windmill design. Windmill blades are responsible for a large portion of the unit's efficiency [8].The blade designer should decide on materials systems that are less cost, more performing, have a low density, have a longer life and can be recycled. These considerations can result in a blade structure that has maximum aerodynamic performance, reduce gravity forces, and reduce material deterioration during operation, resulting in a longer life-cycle. [10]

2)LITERATURE REVIEW

There are mainly two types of wind turbines on the basis of the rotor orientation:[11]

a) Horizontal Axis Wind Turbine(HAWT) b) Vertical Axis Wind Turbine(VAWT)

Gupta studied that Horizontal Axis Wind Turbine (HAWT) is improved when compared to the Vertical Axis Wind Turbine (VAWT). The study showed that the power coefficient was higher for the HAWT while the VAWT had a lower tip speed ratio[3].However, in urban areas, VAWT had better performance in turbulent wind conditions[15].In urban areas, turbulence occured at lower speeds[4] .The VAWTs had a lower turbulence sensitivity. The change of wind direction did not allow the HAWT to perform well in these conditions[15].The VAWT can be further categorized into two based on the aerodynamic forces. The drag type turbine is called the Savonius turbine and the lift-type turbine is called the Darrieus[6].Two or three scoops are sometimes attached to the Savonius turbine which increased the drag force while the scoops are operating in the same direction as that of the wind. The turbine rotates due to the differential drag force [6].The Darrieus turbine has a greater power co-efficient[6].

2.1)Cut-in Speed

The cut-in speed is the minimum speed at which the blades start rotating and producing power. For producing power at lower wind speed, the cut-in speed can be reduced. The highest speed at which the maximum power is produced is known as the rated speed. By lowering the rated wind speed, more power can be produced at a lower rated speed [4].

We can estimate the power output by using Blade Element Moment theory(BEM). BEM is a mathematical model that is used to estimate ideal efficiency as well as flow velocity. [4]. By using BEM theory, we can calculate the aerodynamic forces acting on a turbine blade and then evaluate effective turbine loading and power output[6].

From the figure 1, we can infer that the power is generated once wind speed reaches cut-in speed and that the power becomes constant when rated speed is attained.[11]

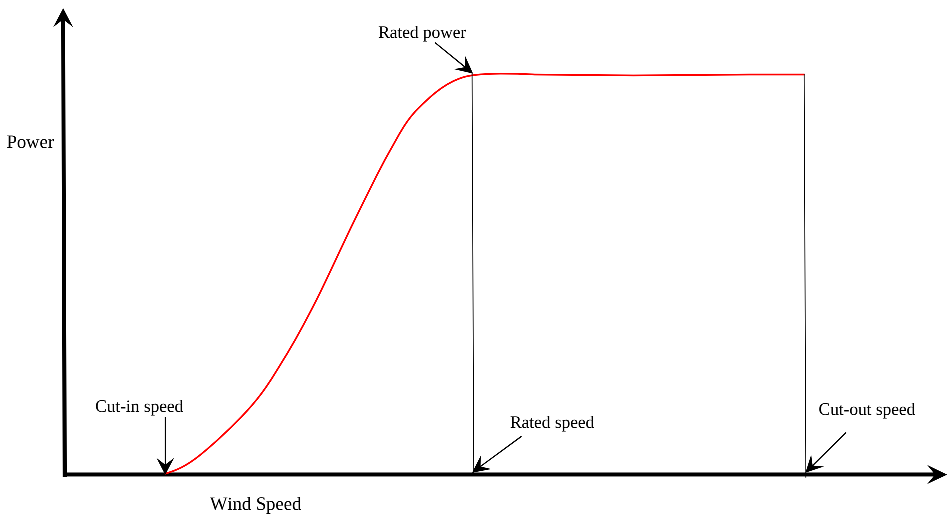

Fig.1: A graph of wind speed in X axis and Power in Y axis [11]

2.2)Material Used

The cut in speed could also be reduced by choosing light materials for the blades. Thinner components also have the potential to improve efficiency by minimizing drag. [8]. Turbine blades are currently fabricated using thermoset materials such as glass or carbon fibre reinforced with thermoset polymers like polyester or epoxy resins. Raghavalu Thirumalai observed that when compared to other fibre composites, carbon fibre had a very superior tensile and compression capacity (figure 2). Aluminum and composite materials have helped to reduce rotational inertia.Increased material costs and styrene emissions were the main disadvantages faced while using these composite blades [10]. The waste management of composite blades also posed a challenge [8].

The composite materials which are used like carbon fiber and glass fiber are comparatively heavier [4]. Dathu et al suggested that lightweight materials for the blades had increased the efficiency. Materials such as Copper-Zinc- Aluminum (Cu-Zn-Al) and Copper- Aluminum-Nickel) alloys reduced the shear stress on the blades and enhanced the power production [4].

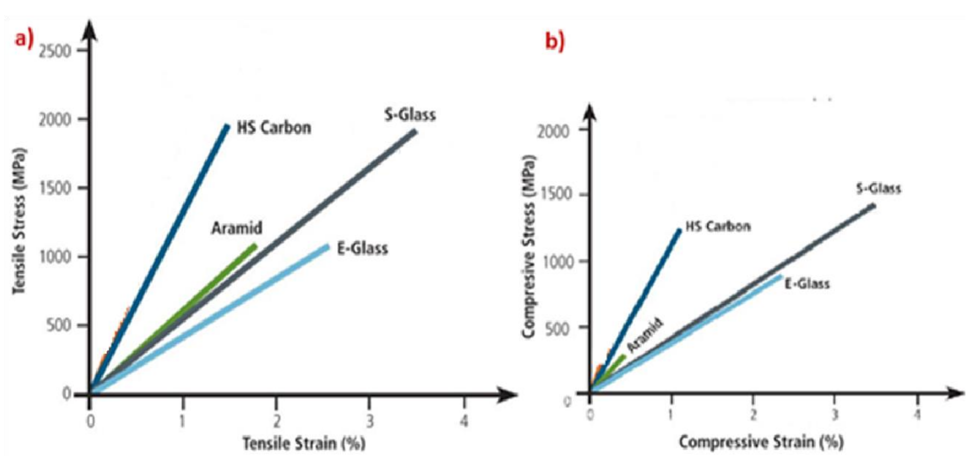

Fig.2.Stress-strain curves of various composites[9]

2.3)Tip speed ratio(TSR)

The tip speed ratio is an important parameter in the design. The TSR is the ratio of tangential speed of the tip to the wind velocity.[4].

- $\lambda = \omega R/V_w$, where λ=Tip speed ratio

  ω=Rotational Velocity

  V_w=Wind Speed [4].

The tip speed ratio varies with the design method utilized, the profile of the rotor airfoil and the quantity of blades [1]. Narrow blade profiles result in higher tip speed. This has resulted in lesser material usage and lower fabrication cost [6]. Laryea at al observed that the power coefficient(Cp) of a rotor differs with the tip speed ratio [15]

Bakirci et al founded that OTSR and power coefficient varied by the blade number. It was observed that higher power coefficient and a lower OTSR was affected by a higher blade number.The TSR for a certain wind turbine design is determined by the design method utilised, blade number and profile of the rotor air foil. The OTSR for grid connected wind turbines with three rotor blades has been reported to be seven, with suitable values varying from six to eight.[1]

Shankar et al studied that TSR of the turbine blade was predicted to be 2.5 times that of incoming velocity and it could reach values of 8 for a high speed wind turbine. [14]Figure 3 shows that a wind turbine must be constructed to operate at its optimum TSR to generate as much power as possible[1].

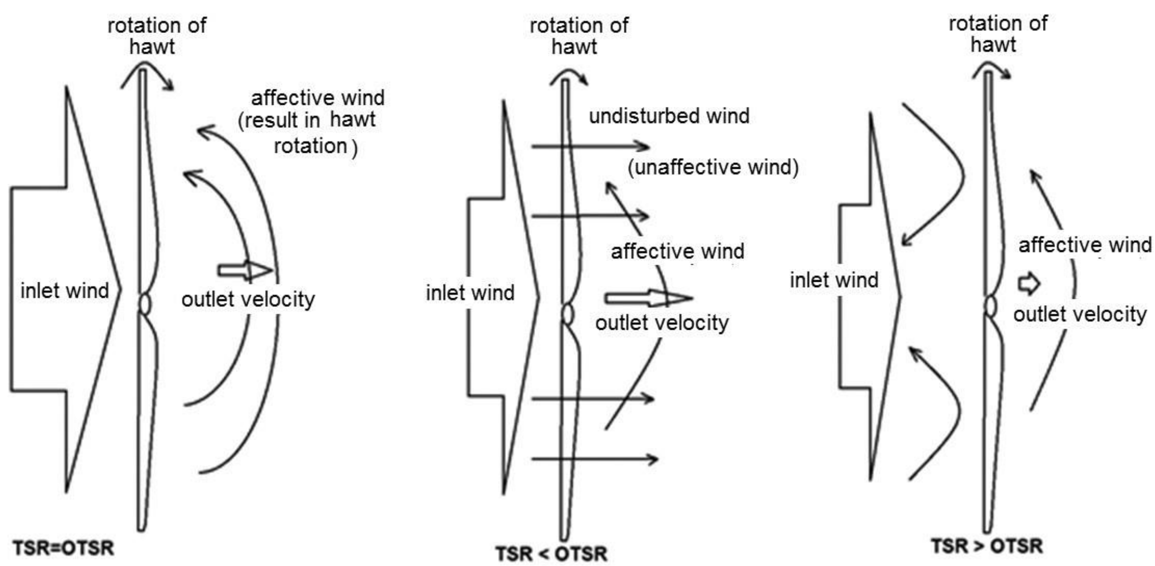

Fig. 3. When the TSR is same as, less than, or greater than the OTSR[5]

2.4)Angle of attack(α)

The angle of attack is the angle formed by the blade and the incidence angle. When the pitch angle is reduced, the angle of attack is reduced, and simultaneously the lift created is decreased. The angle of attack is determined by the twist and pitch of the blade [8],[10]. The ideal angle of attack on an air foil-shaped blade resulted in more lift force to rotate the blade [15].

A phenomenon called stall often arises at high angles of attack, depending on the aerofoil type. It can be used to control the maximum power output to avoid generator overload and excessive forces in the blades at high wind speeds, and it may also occur spontaneously during gusts.An angle of attack of ten to fifteen degrees produces the maximum lift with the least drag on most airfoil blade profiles[15].Schubel et al studied that the lift produced by an aerofoil section is determined by its angle of attack to the inflowing air flow.[13]

3)DISCUSSION

The ways to increase the efficiency of the wind mill blade are discussed in the paper. Some of the means by which efficiency is increased are altering the cut-in speed, materials used, tip speed ratio and angle of attack. The key points are mentioned below.

The materials chosen for the blades can be replaced by lightweight materials. The location of the wind turbine can determine whether it is a horizontal or vertical axis turbine. The wind turbine must be fabricated to function at its optimum TSR to generate maximum power. The ideal angle of attack produced more lift force to rotate the blade.However the land which is available for wind turbine may not be readily available always. The land may consist of different types of relief like hills, valleys and mountains and there may be not sufficient wind speed near the ground[12].Buoyant Air Turbine(BAT) provides a solution to this problem.

4)**FUTURE SCOPE**

Buoyant air turbine(BAT)

Buoyant airborne turbines are turbines which are made of helium filled fabric shell and are tethered to the air at high altitude. They are used to capture stronger winds which blow higher in the air[5].It is also used in off-grid and remote areas and it can produce upto 30 kW of power[3].The aerodynamic design of the aerostat offers lift to the system in strong winds. [12

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