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A Study of Savonius Type Wind Turbines: Its Feasibility in Context to Wind Potential of Guwahati, Assam

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ABSTRACT:This work deals with the details feasibility study of Savonius type of wind turbine in context to Guwahati, Assam. The wind velocity data has been collected for a period of two months when the wind speed happens to be maximum. The data is plotted accordingly to see the trend and get the average value. Now taking this wind velocity as the base different characteristics of Savonius type wind turbine has been constructed to check its performance.

KEYWORDS:tip-speed ratio, swept area, coefficient of performance, vertical axis, feasibility, cut-in speed, Betz constant.

I.INTRODUCTION

With the rising concern over the depleting levels of fossil fuels, power industries are now more inclined towards the renewable sources. Different types of renewable sources have emerged with their own advantages and disadvantages. Wind Power is a very reliable type of source as it is pollution free with low operational cost. For converting the kinetic energy of wind into useful electricity, wind turbines are used. There are mainly of two types of wind turbine, Horizontal Axis Wind Turbine (HAWT) and Vertical Axis Wind Turbine (VAWT). Out of these two, HAWT is the most widely studied and used. The development of VAWTs began lately and many useful features are coming out of this type of turbines most noteworthy being its ability to capture the wind from all directions. The first type of VAWT was developed by Georges Jean Marie Darrieus in 1931 which was named after him as **Darrieus Wind Turbine.** The other type of VAWT was developed by Finnish engineer S. J. Savonius in 1922 and named after him as **Savonius Wind Turbine.** The main difference between these two types of turbine lies in its blades. The Darrieus type resembles an “egg beater” consisting of a number of curved blades attached to a vertical axis rotating shaft. The Savonius type rotor resembles two halves of an oil barrel fixed to two bars which are attached to the shaft. It gives a top view of the letter “S”. This turbine works on the drag force of wind. As air hits any of the barrel section, pressure difference is created between the two sections and rotates the turbine. Unlike Darrieus counterparts, the Savonius turbines are self-starting and do not need any additional starter. These turbines work in relatively low velocity of wind. The have a less tower height and battery and other electrical equipment can be kept in the ground. They are generally utilized for small scale electricity generation and water pumping.

The wind energy potential of Assam is relatively low as compared to the other coastal regions of the country. Moreover, no significant effort has been done in analysing on ways how to harness this small amount of energy to its optimum level. Wind speeds are significantly high only during pre-monsoon season when during thunderstorms and hailstorms occur. Attempts should be made to capture this energy. Out of various locations, Silchar has relatively high wind speed and has the potential of setting up wind power plants. In this study, the wind velocity trend of Guwahati, Assam has been observed on a monthly basis for one year of period, and also on daily basis for three months.The average wind speed is found out to be 5km/hr and peak wind speed is 74km/hr. Though the average is low, but at certain peak times, a good speed can be observed. From these observations, a base speed has been selected. The

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performance of the Savonius turbine is analysed on the basis of these observed wind speed and various parameter values.

II. WIND DATA COLLECTION

First step of doing this study is collecting the wind data and observe the wind trend. For this, the period has been selected as February 15th to April 15th 2018. For this period the wind velocity and direction data has been collected. The data has been collected from the Regional Meteorological Centre, Borjhar, Guwahati. Two plots have been developed. Plot 1 is Wind velocity on daily basis, plot 2 gives the frequency curve (No of days of occurrence) vs. wind velocity.

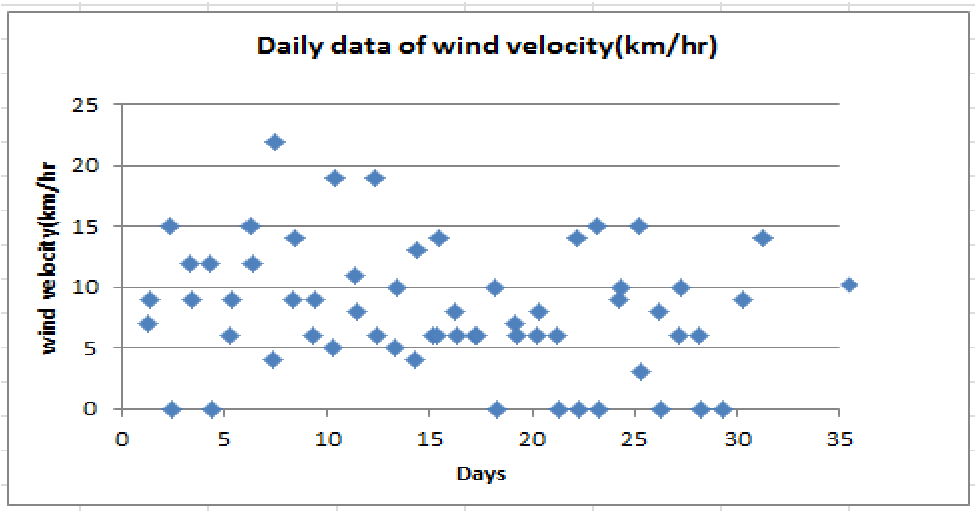

Fig.1: Daily wind velocity data during February15-April15

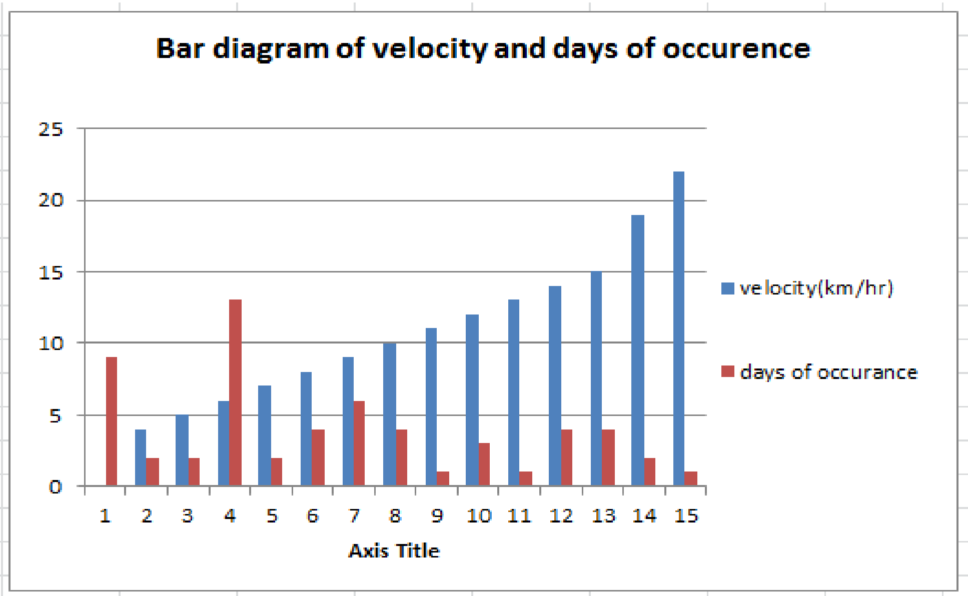

Fig.2: Comparison of days of occurrence and wind velocity

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Fig.1 shows that the wing velocity graph is highly random. This velocity generally lies in the range (5-15)km/hr with a few points above and below the range. From this highly random graph, the analysis becomes difficult. Hence in Fig 2 a bar diagram is developed showing the wind velocity and no of days of occurrence. From this, it is clear that a maximum frequency of 13 occurs at a wind velocity of 4km/hr. and minimum frequency of 1 occurs at a wind velocity of 22 km/hr. From the above data, the average wind velocity happens to be 8.06km/hr. So for this low level of wind velocity, Savonius wind turbine happens to be a good option with low noise and reduced risk of accident.

III. SYSTEM PARAMETERS SELECTION

The vertical axis wind turbine operates on the principle of drag force of wind. To compensate for its low rotating speed, a gearbox can be attached to the rotor shaft to increase it to desired level. The power generated in watt by a Savonius wind turbine can be given by,

$$P=0.5C\rho Av^3 \qquad \text{(i)}$$

Where, ρ=air density, the nominal value will be considered to be 1.225kg/m^3

C_p=coefficient of performance, which is used to designate the efficiency of the entire turbine power system generally defined as $\mathbf{P_{out}/P_{in}=4a(1-a^2)}$ where a is the axial induction factor.Maximum value of C_p is**0.593** which is known as **Betz constant**.

A=Frontal area or swept area in m^2, it is the plane of the wind intersected by the generator which is the multiplication of height of the blade(H) in m and diameter of the wind(D) in m

v=velocity of the wind in m/s

Other important parameters are ,

Tip-speed ratio(α): It is given by $v_{rotor/}v_{wind}$i.e. the ratio between the tangential speed of the tip of the blade and actual speed of the wind. For Savonius generators, value of α lies between 0 and 1

Cut-in-speed: It is the initial speed at which the turbine starts to rotate and generate power. Its value is generally 3-4 m/s. It is less than the rated speed of the turbine.

Cut-out speed: Cut out speed is the maximum speed for a particular turbine at which the rotation is stopped intentionally to avoid any damage caused to the blades. Its value is generally 55-56 m/s. It is the highest speed of the turbine.Bigger the diameter, lower the rotational speed. Bigger blades do not increase the rotational speed but increase the efficiency of the turbine.

Axial induction factor (a): It may be defined as the fractional decrease in wind velocity between the free stream and the rotor plane, $a=(v_1-v_2)/v_1$

We consider the following parameters as the nominal values of the turbine:

Parameter	Value
α	$0<\alpha<1$
C_p	0.3
ρ	1.27 kg/m^3
A(H*D)	6.1m*1.2m
Rated capacity	1.2 KW

Table 1: Nominal parameters of the turbine

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V. PERFORMANCE ANALYSIS

By taking into account the values of the wind speed and other parameters, we observe how well the Savonius turbine will work under different operating conditions. These observations are plotted in different graphs as shown below:

1. Power Output vs.Wind speed curve

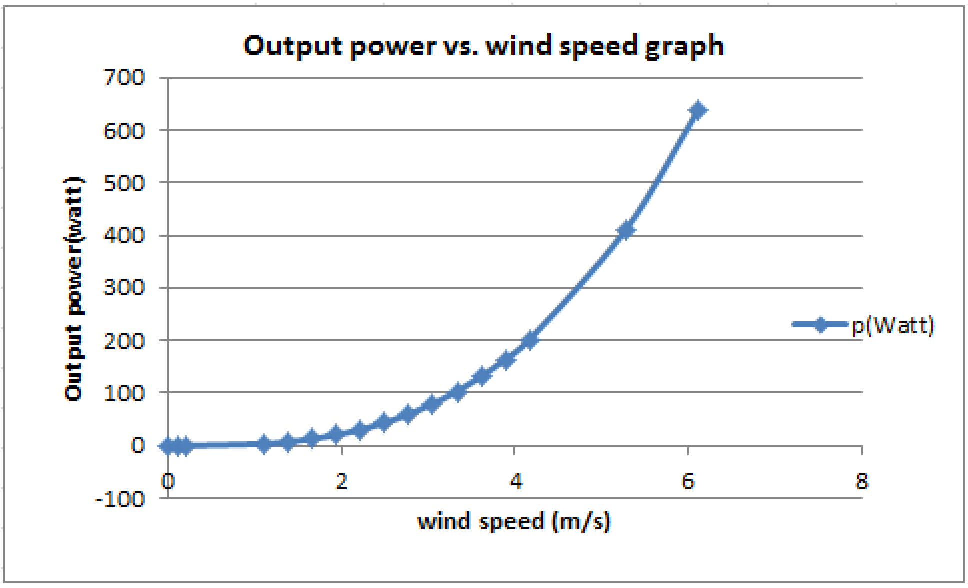

Fig.3 Power output vs. speed curve

2. Effect of increase of rotor diameter on available power

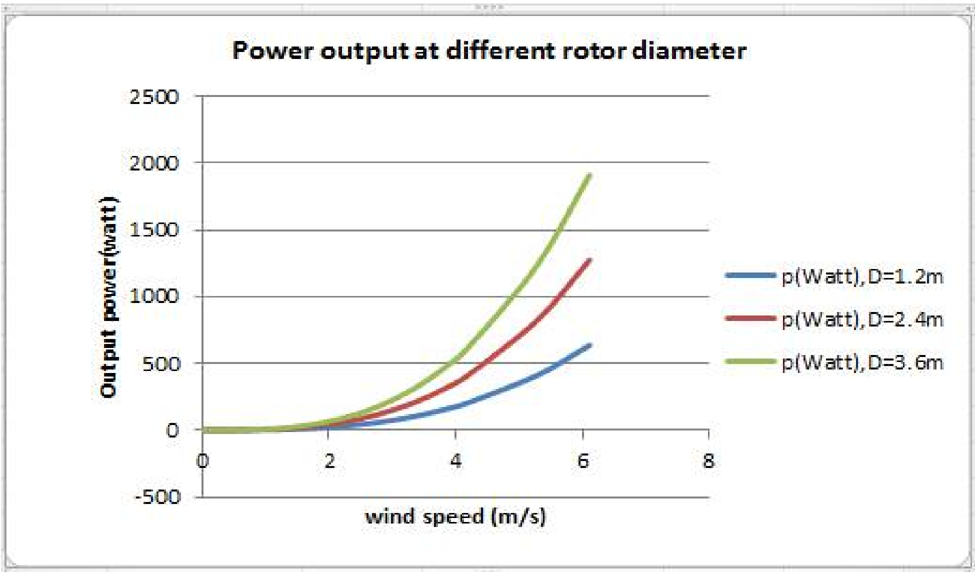

Fig.4 Power output at different rotor diameter

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3. Effect of axial induction factor on coefficient of performance

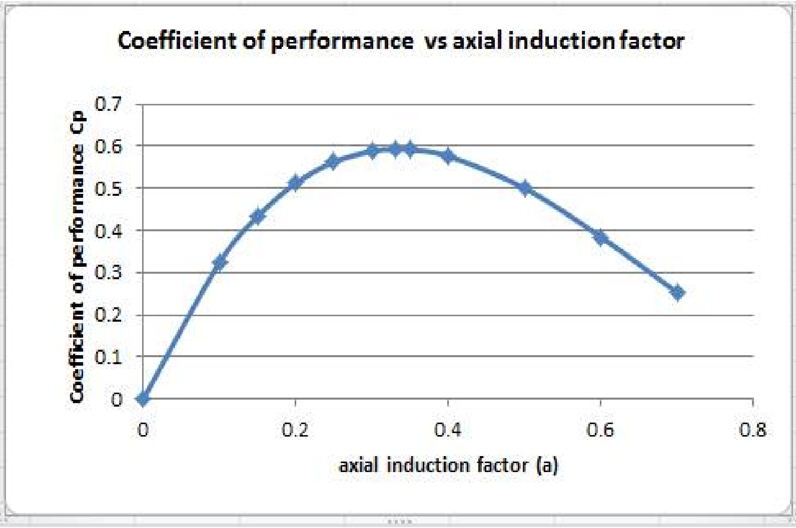

Fig.5 Coefficient of performance vs. axial induction factor

4. Relation between coefficient of performance and tip-speed ratio

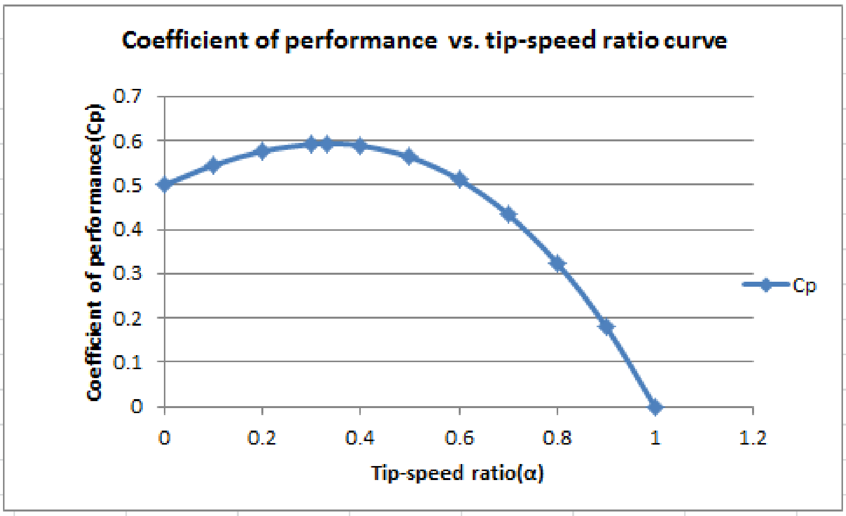

Fig.6 Coefficient of performance vs. tip-speed ratio

The performance of Savonius rotor wind turbine has been analysed taking into account the practical values of wind speed. The rotor we have considered has a rated capacity of 1.2 Kw. After plotting the values of generated power against the wind speed in fig.1, it was observed that the cut-in speed happens to be around 0.2 m/s with a generated power of 0.022 watt. The maximum power obtained is at a speed of 6.11 m/s and power is 0.636 kW. So it can be noted that at this level of wind speed, without using any gear-box, only half the rated capacity of the turbine can be harnessed. Hence it may be advisable to use gearboxes.

Fig.2 shows the increase in power produced with increase in the diameter length of the turbine blades. So with increase in blade diameter power will be increased but rotational speed will be decreased.

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Fig.3 shows that for increasing value of axial induction factor, the coefficient of performance attains traces a curve with a maximum Cp value of 0.593 at a=0.33.
Fig. 4 plots the relation between the coefficient of performance Cp against the tip-speed ratio α. It can be observed that for zero value of tip-speed ratio, the Cp value is 0.5 and it becomes maximum at α=0.33 and again go on decreasing.

VI.CONCLUSION

After analysing the different characteristics of Savonius wind turbines, the output is low at the observed value of wind data. Therefore installing a plant for electrical generator may not be commercially feasible, but still it can be useful for domestic use or experimental analysis. Speed improvement can be done using gear arrangements. There is still a large scope of research in this area.

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