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EXPERIMENTAL ANALYSIS OF COMBINE DARRIEUS AND SAVONIUS WIND TURBINE

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ABSTRACT

Due to the increasing environmental and economic cost of fossil fuels, alternative sources of energy are needed. One such source is energy wind energy. Much of the current wind turbine research focuses on large-scale wind turbines. An alternative approach is small-scale wind turbines designed specifically to produce power at low wind speeds. This research work carried out for design small-scale wind turbine by analytical method.

Keywords: Blade Design, Darrieus, Renewable Energy, Savonius, Wind Turbine, etc.

I. INTRODUCTION

Wind energy is a source of renewable power which comes from air current flowing across the earth's surface. Wind turbines harvest this kinetic energy and convert it into usable power which can provide electricity for home, farm, school or business applications on small (residential), medium (community), or large (utility) scales. Wind energy is one of the fastest growing sources of new electricity generation in the world today. These growth trends can be linked to the multi-dimensional benefits associated with wind energy.Non-Renewable energy sources are limited in their availability. In non-renewable energy sources are to be of Coal, Nuclear Energy, Oil, Natural Gas etc. and the renewable energy sources are to be Wind Energy, Hydro-Electric Energy, Solar Energy, Alternative fuels, Geothermal Energy etc. These renewable energies are widely available in nature. Therefore, the renewable resources, when compared to the non-renewable resources, are more unpredictable in their outcomes and also give an outcome are efficiently lower.

A Wind Turbine is a rotary device that extracts energy from the wind and it converted kinetic energy from the wind into electrical power. If the mechanical energy is used directly by machinery, such as for pumping water, cutting lumber or grinding stones, the machine is instead converted into electricity. The machine is called a wind generator, wind turbine, wind power unit (WPC), wind energy converter (WEC), or aero generator. Today's wind turbines are manufactured in a wide range of vertical and horizontal axis types. The smallest turbines are used for applications such as battery charging for auxiliary power for boats or caravans or to power traffic warning signs. Slightly larger turbines can be used for making small contributions to a domestic power supply, while selling unused power back to the utility supplier via the electrical grid. Arrays of large turbines, known as wind farms, are becoming anincreasingly important source of renewable energy and are used by many countries as part of a strategy to reduce their reliance on fossil fuels [1].

Despite of a great success in the extraction of the powerthrough wind turbines the same has also been accompanied byfew limitations. The wind turbines have to be placed in the windfarms with minimum allowable

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spacing where there is no effectof eddies generated at the downstream of the preceding wind turbines[2]. Wind is an environment friendly source of energy that has got huge potential to satisfy energy needs for people and also to mitigate the climate change from greenhouse gasses emitted by the burning of fossil fuels. It was estimated that roughly 10 million MW of energy are available in the earth's wind. The International Energy Agency (IEA) showed the global cumulative wind power capacity worldwide based on the projection in the 2004 World Energy Outlook report[3].

II. WIND TURBINE THEORY

2.1SAVONIUS WIND TURBINE

As a simplest turbine, Savonius wind turbine works due to the difference of forces exert on each blade. The concave part to the wind direction caught the air wind and forces the blade to rotate around its central vertical shaft. Otherwise, the convex part hits the air wind and causes the blade to be deflected sideway around the shaft. The blades curvature has less drag force when moving against the wind or F_{convex} than the blades moving with the wind or $F_{concave}$ as seen in Fig. 1[4] Hence, concave blades with more drag force than the other half cylinder will force the rotor to rotate.

The performance of Savonius wind turbine can be expressed in the form of torque coefficient (Ct) and the coefficient of power (Cp) in comparison with the tip speed ratio or TSR (λ). TSR is a parameter related with rated wind speed and rotor diameter. As the ratio between the speed of tip blade and wind speed through the blade, TSR can be determined as[5]

TSR = λ = = ………………… (1)

Where,V_{rotor} is the tip speed or the peripheral velocity of rotor (m/s); ω is the angular velocity of rotor (1/s); d is the diameter of the halves cylinder of rotor (m), and V is the wind speed (m/s). The coefficient of torque or C_t is defined as the ratio between the actual torque develop by the rotor (T) and thetheoretical torque available in the wind (T_w) as,

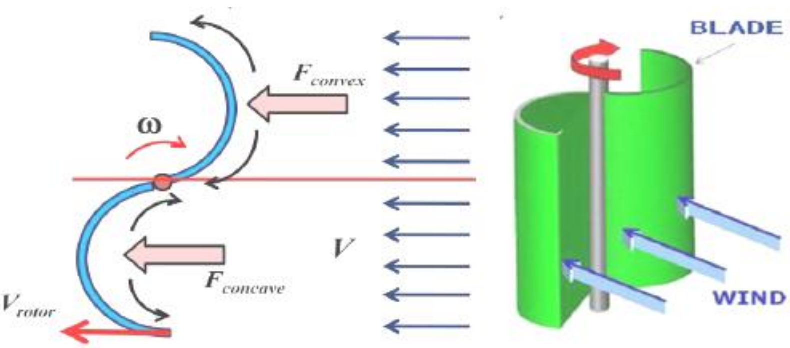

fig.1Two blades Savonius wind turbine with the drag forces

Ct = = $\frac{4}{\rho A_g}$………………… (2)

Where, ρ is the density of air (= 1.225 kg/m3); T is the torque (Nm), and A_s is the swept area of blades = the rotor height x the rotor diameter (m^2).

The coefficient of power of a wind turbine (C_p) is the ratio between the maximum power obtained from the wind (P_t) and the total power available from the wind (P_a) as,

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$C_p =$ =   ………………… (3)

where the maximum power of wind turbine is determined as

$$P_t = T\,\omega \text{ (Watt)} \quad \ldots\ldots (4)$$

2.2DARRIEUS WIND TURBINE

After the WWI, G.J.M. Darrieus, a French aeronautical engineer, invented a VAWT by adopting airfoil profile for the blades. Hepatented the design in France in 1925 and in the US in 1931 and put the working principle as a biomimicry of birds' wings by stating, "It is thus possible to give these blades a stream line section analogous to that of the wings of birds, that is to say, offering the minimum resistance to forward movement and capable of converting into mechanical energy the maximum available amount of energy of the fluid by means of the useful component of the traverse thrust which this section undergoes"[6]

The curved and straight-blades configurations have evolved intoseveral variations, as shown in Fig. 2 Curved-blades configurationhas been known as egg-beater or phi-rotor due to the similar look.There are several variations of phi-rotor, such as guy-wired, fixedon-tower and cantilevered versions (details on these types areavailable in the following sections). Similarly, straight-bladesconfiguration has several variations. Diamond, V/Y and delta (D)variations have been documented [7, 8]. Another variation, avariable-geometry VAWT or often called Musgrove-rotor had beenreplaced by fixed-pitch H-rotor (referred only as "H-rotor" in thispaper for simplicity). Currently, H-rotor has been actively investigated,including multi-megawatt rotor for offshore application.

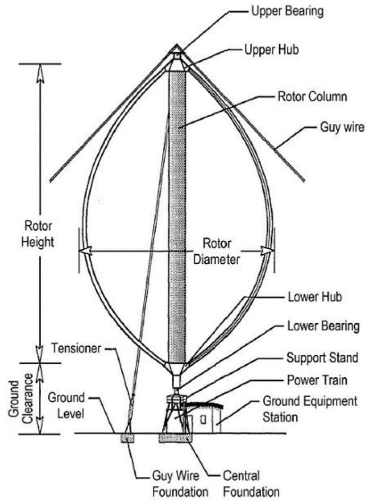

fig.2 General view of darrieus turbine

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III. DESIGN ANALYSIS AND METHODOLOGY

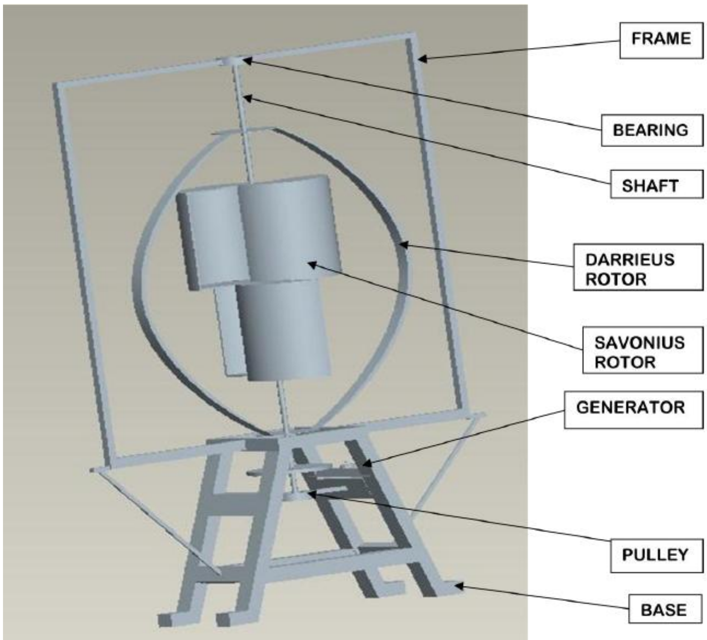

fig.3 CAD Modelling of Savoniusand Darrieus wind Turbine

3.1 Calculation of Savonius Rotor Blade:

For design purpose we are taking a diameter of Savonius rotor

D=750mm

Therefore, maximum wind speed during past 20 year in Vadodara = 74 km/hr = 20 m/sec

And average wind speed during a year = 3.07 km/hr = 0.8527 m/sec

Here, we are designing our wind turbine for maximum wind condition. So,it can withstand and give power during high andmaximum wind flowing condition also.

3.2 Design of Maximum Wind Condition:

V (max) = 20 m/sec

D = 750 mm

H = 400 mm

Now, power (P) = $\frac{1}{2} \times \varrho \times A \times V^3(\text{max})$

$P = \frac{1}{2} \times 1.25 \times 2D \times H \times (20)^3$

$P = \frac{1}{2} \times 1.25 \times 2 \times 0.75 \times 0.4 \times (20)^3$

P = 3000 watt = 3 kW

Average power (P) = $\frac{1}{2} \times \varrho \times A \times V^3$ (avg)

$P_{avg} = \frac{1}{2} \times 1.25 \times 2 \times 0.75 \times 0.4 \times (0.8527)^3$

P_{avg} = 0.23 watt

We know that for our project I = 0.2 amp

$P_{avg} = V \times I$

$0.23 = V \times 0.2$

$V = 1.15$ volts

Now, $P = T \times \omega$

We have P(max) = 3000 watt and P(avg) = 0.23 watt.

From, that $(T_{max}) = \frac{1}{2} \times \varrho \times A \times V^2 \times R$

$T_{max} = \frac{1}{2} \times 1.25 \times 2D \times H \times V^2 \times D/2$

$T_{max} = \frac{1}{2} \times 1.25 \times 2 \times 0.75 \times 0.4 \times (20)^2 \times (0.75/2)$

$T_{max} = 56.25$ N.m

Now, $P(max) = T(max) \times \omega$

$\omega(max) = P(max) / T(max) = 53.33$ rad / sec

$\omega(avg) = P(avg) / T(avg) = 3.3744$ rad / sec

3.3 CALCULATION OF DARRIEUS ROTOR BLADE:

We are taking aero foil shape for better performance and lowering the drag force.

Taking overall length H = 1000 mm, R = rotation radius and D = rotation diameter

Maximum cross section of aerofoil = 300 mm²

$T(max) = \frac{1}{4} \times \varrho \times H \times V^2 \times D^2$

$56.25 = \frac{1}{4} \times 1.25 \times 1 \times 20^2 \times D^2$

D = 0.670 meter = 670 mm

Angular velocity $(\omega) = 2\pi N / 60$

$N = \omega \times 60 / 2\pi$

Therefore, N (max) = 509.26 r.p.m

N (avg) = 32.31 r.p.m

So, diameter of shaft

$T(max) = \pi/16 \times \tau \times d^3$

$56.25\times10^3 = \pi/16 \times 50 \times d^3$

d = 17.89 mm say 25 mm

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IV. EXPERIMENTAL SETUP

fig.5 Experimental setup

On the Testing was done at the terrace of our home. At that time the wind velocity was around 2-3 km/hr. so the turbine was not rotating as high as our expectation. Due to problem of bending of the outer blade for reasons of airfoil shape cannot bend properly. so that the sufficient amount of torque of wind turbine is not produce at a higher speed. Therefore, we could not get power that we were expecting. But at the time of second test at the same place, the wind velocity is around 3-6km/hr our turbine rotates at around 20 rpm and by applying new arrangement we can get around Voltages up to the 0.7-2.1 volt. At the end we are going to success to lighting the LEDS.

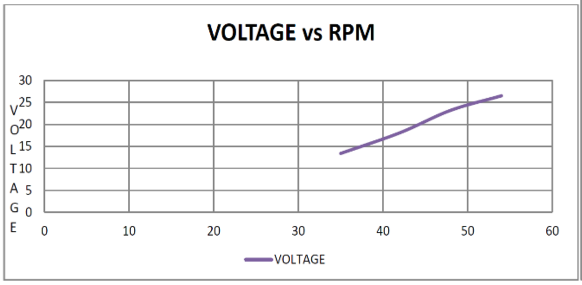
During the testing the Wind Turbine shows the following Readings. The Reading that we get it is of the prototype model of Wind Turbine. It can be increased by using higher capacity generator and some modification in rotor Design.

Table 1. Observation table

Wind Velocity (km/hr)	Rotor Speed (RPM)	Voltage (V)	Current (A)
3.98	14	1.1	0.43
5.01	17	1.4	0.58
6.08	19	2.1	0.77

V. RESULT ANALYSIS

From the Practical Observation the Following Graphs can be made. This observation is taken from the Wind Turbine. There are so many chances that it going to very much increase up to its 50% efficiency in actual Turbine.



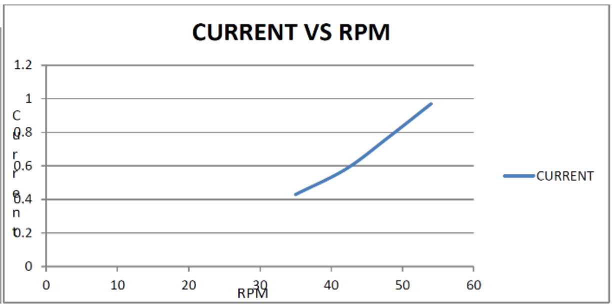
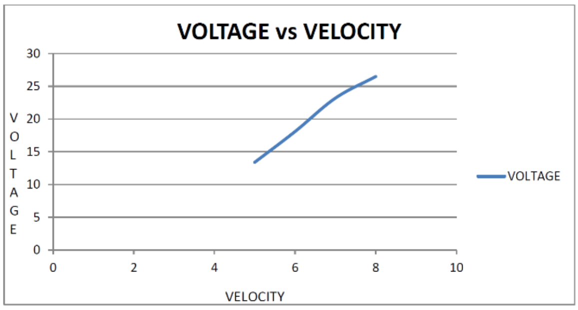


fig.6Voltage v/s RPM

fig.7 Current v/s RPM



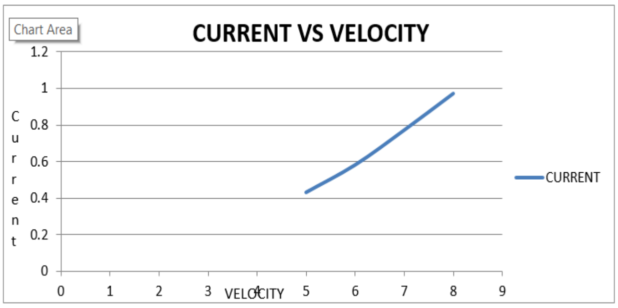


fig.8 Voltage v/s Velocity

fig.9 Current v/s Velocity

Above graph represent regarding experimental results its shows that wind velocity increase than rpm of rotor is increase regarding this purpose produce electricity in terms of voltage and current is also increase.

VI. CONCLUSION

The aim of the research work is the wind turbine produce less electricity and its efficiency is lower even wind turbine is very large. And also due to large size of wind turbine blade, their swipe area of blade becomes large. For increasing electricity there is a need to design blade of wind turbine by reducing its swipe area. Therefore, due to these the wind turbine farm is to increasing the capacity of the installing the number of wind turbine so that power producing capacity will be increasing. The Initial goal of this project was to come up with a self-starting mechanism for a typical Darrieus wind turbine and get higher efficiency of Savonius Wind turbine. However, the solution attempted was anything but typical, resulting in a totally new combination of Darrieus and Savonius Wind Turbine. This new combination that was developed probably has more potential. This potential has not yet been completely realized, but the concept has been proven to function as a self-starter and get higher efficiency. This design fills the functions required of a starting mechanism; it is mainly the inaccuracy of the blade profiles that led to less than desirable results during testing. Most of the tough design problems have been resolved, so another group could easily concentrate on fabricating quality blades and improving the overall design. With a sufficient time, this design could easily be developed to capitalize on the potential which has been discovered. The concept that has been proposed has much room for future development.

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