DESIGN, ANALYSIS AND FABRICATION OF MULTI-PURPOSE DUAL ROTOR

Shlok kadam[1], Abhishek Shinde[2], Ankit Shah[3], Bharat Kapadiya[4]

[1] Student, mechanical, V.I.E.R., Gujarat, INDIA
[2] Student, mechanical, V.I.E.R., Gujarat, INDIA
[3] Student, mechanical, V.I.E.R., Gujarat, INDIA
[4] Asst.Prof. , mechanical, V.I.E.R., Gujarat, INDIA

ABSTRACT

Electric power has become a great requirement for today's world globally. And it seems certainly impossible to survive without it as each and every activity of human depends and includes electrical gadgets, appliances and machines. All of these require electricity to run and thus consume a high rate of energy each day. Approximately there is 18,000 TWh consumption of electrical energy per year all over the world. Thus to generate this large amount of energy it requires large amount of natural or artificial resources. Hence the most economical of them are the natural resources that are used to generate energy at comparatively low cost and in large quantity. But the major problem that we are facing is the diminishing natural resources such as petroleum base fuels and coal, minerals such as uranium, caladium, etc.

As a result we are left with the never ending or say renewable resources such as wind, solar and tidal energies to generate the high quantity of electrical energy required. These sources of power generation are the most efficient and economical. With these they are even free of cost and are of no one's authority. This means that they are free to all and in abundance. So as to take great advantage from this and to use the resources in the optimum manner is our main aim.

Thus to generate energy from renewable natural sources such as wind, solar and tidal energy we require a group of mechanisms which converts the kinetic and solar energy of the sources into electrical energy. And for this purpose we are aiming to produce a modern transformation of a wind mill rotor which would generate power more efficiently and effectively.

Keyword: - *Dual rotor, Diffuser, Drafted wind turbine*

1. INTRODUCTION

Power has been generated from the wind from more than thousands of years with the help of traditional designs of wind turbine and other mechanism, constructed from wood, cloth and stone for the purpose of pumping water or grinding corn. Later on heavy metallic materials came into application for better performance and efficiency. This brought a revolutionary change in the field of power generation as it was effective form of power production. A greater understanding of aerodynamics and advances in materials, particularly polymers, has led to the return of wind energy extraction in the latter half of the 20th century. Wind power generating devices are now applied in generation of electricity, and are commonly known as wind turbines. The characteristic of the shaft and rotational axis determines the classification of the wind turbine. A turbine with a shaft mounted horizontally parallel to the ground is known as a horizontal axis wind turbine or (HAWT). A vertical axis wind turbine (VAWT) has its shaft normal to the ground.

1.1 Problem statement

To fulfill the demand and usage of electrical energy throughout the entire globe high power generation is inevitable. But the generation of this high amount of electricity from any group of mechanisms and by using any form of energy should be cost effective as well as it should not cause any harm to the nature.

1.2 Problem identification

There are many different ways to generate electrical energy and the most efficient of them are to generate electricity with the help of renewable natural resources. As renewable natural resources are in abundance we do not need to worry about its extinction and it is even free of cost. Whereas if we generate electricity from sources such as petroleum fuel products, coal or other such non renewable resources then it would turn out to be very costly method of power generation. In this case we need to produce the electricity from renewable natural resources by taking an advantage of the same as it is in abundance. It is possible to generate electrical power from the wind energy, tidal energy and solar energy as well, as these all three forms are renewable form of resources.

Wind mills are of various types and kinds depending upon the requirement and characteristics and they have been modified every now and then for better performance of power generation from the available quantity of resource. It converts the kinetic energy of the blowing wind into mechanical energy with the help of rotor and blade assembly which is connected to the shaft. This shaft is eventually connected to the generator and as the rotor and blade assembly rotates with the help of wind velocity, the shaft connected to it also rotates and in turn generates electricity when connected to generator. But still there is wastage of the available kinetic energy from the blowing wind, these means the kinetic energy of the wind is not completely used or converted into the mechanical energy and later into electrical energy. This is wastage of the resource and to overcome that an effective design of the wind turbine rotor and the wind turbine is to be generated. Thus the main problem that we need to overcome is the design of the wind turbine.

1.3 Aims and objectives

The aim of this project is to produce a design of complete wind turbine assembly with additional parts in such a way that it would generate comparatively more power than the traditional wind mill. The task of making a compact turbine would be in context with accelerated wind turbine and lighter in weight. To generate a design more effective and efficient there should be high kinetic energy conversion to mechanical energy. And for this an installation of diffuser will be of great help to generate more amount of energy and as a result to produce more mechanical and electrical energy.

Under the main objective there are various other areas of improvement such as light weighing construction. This can be implemented with the help better and lighter material and reduction in size of the turbine and other components. Flexible in installation and domestic usage, effective co-axial rotor blades assembly and smaller sized design.

2. DESIGN OF ROTOR BLADES

2.1.1 Design Methodology:

In this turbine rotor both wind rotors start to rotate at low wind speed, namely cut in wind speed, but the rear wind rotor counter rotates against the front wind rotor. The increase of the wind speed make the both rotational speeds increase, and the rotational speed of rear wind rotor becomes faster than that of the front wind rotor because of its small size. The rear wind rotor reaches the maximum rotational speed at rated wind speed. With more increment of the wind speed, the rear wind rotor decelerates gradually and begins to rotate at the same direction of the front wind rotor so as to coincide with larger rotational torque of front wind rotor.

Such behavior of rear wind rotor is induced from the reason why the small sizes wind rotor must work as the blowing mode against the attacking wind because the wind rotor turbine mode can or cannot generate adequately the rotational torque corresponding to the front wind rotor. The behavior of the front and rear wind rotors also depends on the blade profiles and flow condition between both rotors, and will be discussed. The rotational direction and speed of the rotors are adjusted in response to the wind circumstance.

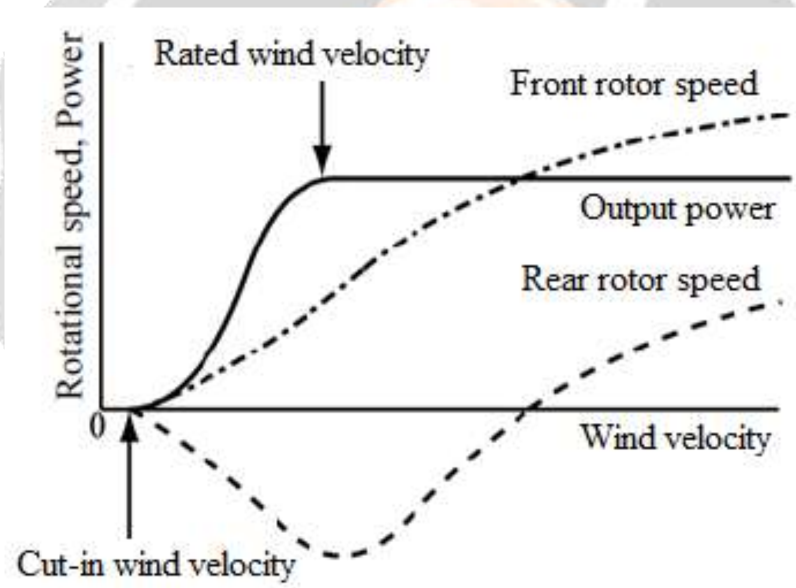

Fig. Operation of co-axial rotor

2.1.2 Design Calculation:

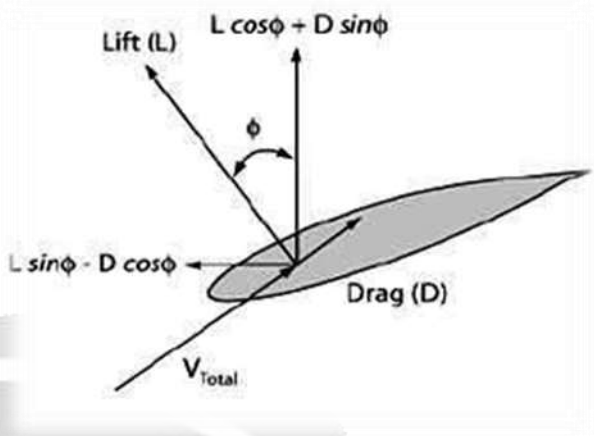

Fig. Local elemental forces

Nomenclature

A = Area
a = Axial induction factor
a' = Radial Induction factor
B = Number of blade
C_d = Drag coefficient
C_l = Lift coefficient
c = Chord length
C_p = Power Coefficient
D = Diameter
F_x = Axial Force
g = Acceleration of gravity
L = Lift force
P = Power
p = pressure
Q = correction factor
r = local radius element rotor
Re = Reynolds number
R = Radius
T = Torsion
ΔT = Thrust
Vo = Absolute Velocity
W = Relative velocity
u = Tangential velocity
x = Local speed ratio
α = angle of attack (AOA)
β = stagger angle
e = Ratio coefficient Lift and Drag
γ = pitch angel
η = Efficiency
λ = Tip speed ratio
ρ = density angle of attack relative
σ = Solidity
Ω = Angular velocity

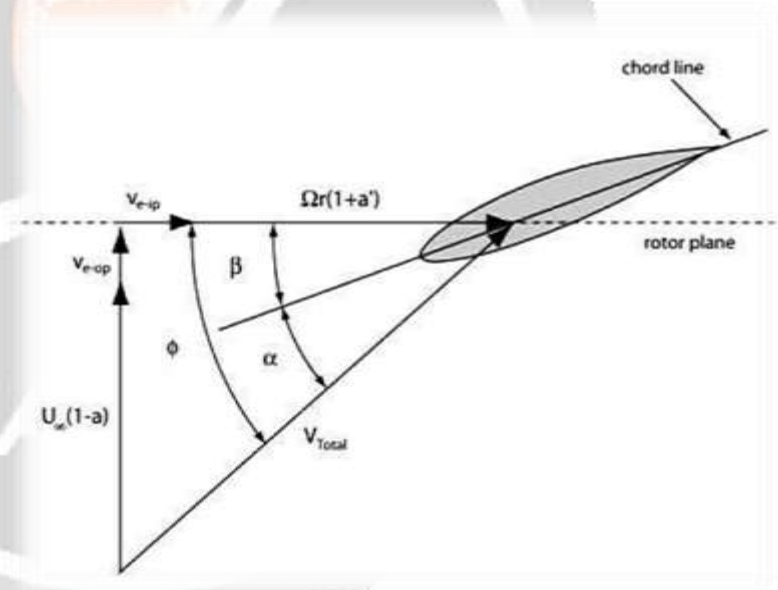

Fig. Local element velocities and flow angles

For torque:

$\Delta Q = ½ \rho W^2 r (C_L \sin\Phi - C_D \cos\Phi) Bc\Delta c$ ………. (1)

For power:

$\Delta P = \Omega\Delta Q$

$= ½ \rho W^2 \Omega r (C_L \sin\Phi - C_D \cos\Phi) Bc\Delta c$………. (2)

For thurst:

$\Delta T = ½ \rho W^2 (C_L \cos\Phi - C_D \sin\Phi) Bc\Delta r$ …………(3)

Where,

$W = u/\sin\Phi = (r\Omega + w)/\cos\Phi$

$C_p = (1-a)^2 + (1+ \cot^3 \Phi) 4x\lambda(\sin\Phi – \varepsilon \cos\Phi)$………(4)

Calculation of Rotor (Blade) Size :

Area of the rotor = Total annual energy required/Real annual energy density

Power Rating of Windmill

= Actual power density × area of rotor
= ½ × air density × $(\text{velocity})^3$ × area of rotor……….(5)

Tip Speed Ratio:

TSR = ωR/V

where,
ω – Angular speed in radians
R – Rotor blade radius in meter
V – Wind Speed in m/s

Chord Length 'C' = 0.25 m

Span of airfoil 'L' = 1.25 m

Velocity of the airfoil 'U'= 60 rpm × R

Lift Force:

$F_L = C_L \times \rho \times A \times U^2/2$
$F_L = C_L \times \rho \times (C \times L) \times U^2/2$

Drag Force:

$F_D = C_D \times \rho \times A \times U^2/2$
$F_D = C_D \times \rho \times (C \times L) \times U^2/2$

Design of Shaft:

Torque transmitted by the shaft = FL × Length of the blade

2.1.3 Annual Energy Requirement for a Single Home :

The energy consumed by a single home in rural area is,

Consider,

2 bulb of 20 watt per hour (CFL)
= 2 × 20 = 40 watt

1 Fan of 40 watt per hour
= 1 × 40 = 40 watt

1 TV set 10 watt per hour
= 1 × 10 = 10 watt

1 Freeze of 10 watt per hour
= 1 × 10 = 10 watt

So, total energy consumption is 100 watt per hour approximately.

Total annual energy consumption
= Energy consumption per hour × total annual hour's
= 100 × 8760
= 876000 Wh

But this is the energy when wind will flow at rated wind speed throughout the year, which is never a case. Therefore in order to get realistic energy output, we have to multiply the above numbers by the Capacity Factor (CF). For wind energy capacity factor is assumed to be 30%.

Annual Energy Production
= Energy consumption/ hour × total annual hour's × CF
= 100× 8760 × 0.3
= 262800 Wh

2.1.4 Calculation of Power Density of Wind (Power per Unit Area):

Ideal Power density of air (15 meter height is considered)
$= \frac{1}{2} \times \text{air density} \times (\text{velocity})^3$
$= 0.5 \times 1 \times (5 \times 5 \times 5)^3$
$= 62.5\ \text{Watt/m}^2$

Actual power density that will be converted to useful energy
= Power density × [Cp× transmission losses × generator losses]

Considering losses,
- Coefficient of performance = 0.40
- Transmission losses (rotor to generator) = 0.90
- Generator losses = 0.90

Overall loss factor = Cp × transmission losses × generator losses
= 0.40×0.90×0.90
= 0.324

Actual power density
= 62.5 × 0.324
= 20.25 W/m^2

Annual energy density (useful)
= 20.25 × 8760
= 177390 Wh/m^2

By considering the capacity factor (30%)

Real annual energy density
= 177390 × 0.30
= 53200 Wh/m^2

Calculation of Rotor (Blade) Size

Area of the rotor
= 262800/53200
= 4.94 m^2

Radius of the rotor blade (*R*),
$R^2 = 4.94$
R = 1.25 m

Power Rating of Windmill
= 20.25 × 4.94
= 100 watt

Tip Speed Ratio
TSR = (2πN/60 x 1.25)/5
= (2π x R)/5
= (2π × 1.25)/5
= 7.85/5
TSR = 1.6
= 2
So, number of blades would be 08 to 12.

Design of Rotor Blade:
Design of rotor blade of Prototype
Chord Length 'C' = 0.25 m
Span of airfoil L = 1.25 m

Velocity of the airfoil 'U'= 60 rpm × R
= 60 × 1.25
= 75 m/s

Coefficient of Drag (C_D) = 0.1
Coefficient of Lift (C_L) = 1.3

Lift Force
FL = 1.3 × 1 × (0.25 x 1.25) × 752/2
FL = 1142.57 N

Drag Force
FD = 0.1 × 1 × (0.25 x 1.25) × 752/2

FD = 87.89 N

Design of Shaft

= 1142.57 × 1.25

=1428.21 Nm

Torque transmitted by the shaft = $\pi/16 \times \tau \times d3$

where,

τ = Shear stress of Mild steel is 42 MPa = 42 N/mm^2

d = Diameter of the shaft in mm

=1428.21 × 103

= $\pi/16 \times 42 \times d^3$

d^3 = 1428.21/(0.19634 x 42)

d = 55.74 mm

3. OBJECTIVE

The most important addition would be the implementation of a diffuser, in other words a duct surrounding the rotor blades. This improves the flow path of the wind and helps to generate a vortex which will run the turbine at very high speed. With all these improvements in traditional wind mill there will be high rate of power generation as the kinetic energy will be produced more.

5. CONCLUSIONS

The compact and small scale wind turbines such as one designed above, with a diffuser around the rotor blade assembly would result in increasing the wind velocity and this would lead to more kinetic energy. More amount of kinetic energy would provide more power generation. Now at due to coaxial rotors of this design there will be comparatively more percentage of power generation from the same quantity of kinetic energy as compared to single rotor turbine.

So the arrangement of this design with a core features such as the duct or diffuser and a coaxial rotor with inversely rotating blades would provide us high quantity of electrical energy from the same wind speed as compared to simple single rotor turbine. Thus adopting the above design would be beneficial in all terms instead of a simple, huge and single rotor turbine.

6. REFERENCES

[1]. V. B. Bhandari,” Design Of Machine Elements”1st Edition, Tata McGraw Hill Education, 2007.
[2]. Dr. P.C.Sharma & Dr. D.K.Aggarwal,”Machine Design (SI Units)”11th Edition, 2011.
[3]. M.H. Annaiah, “Design of Machine ElementsII”1st Edition, 2010.
[4]. Mohammed**.** Mukhtar Alam**,** D**.**N**.** Naresh**,** Girish Chitoshiya, “Machining and Machine Tools”2nd edition, 2014.
[5]. M/S. Kalaikathir Achchagam, “Design Data”, Revised Edition, 2013.
[6]. K. Gopinath and M.M. Mayuram, Lecture notes, Machine design II, Indian institute of technology, Madras, Pp.1-19.
[7]. R.S. Khurmi and J.K. Gupta “Machine Design” Eurasia Publications, Revised edition 2010.