Design and Fabrication of Vertical Axis Wind Turbine with Magnetic Repulsion

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***Abstract*— In today's life, with the increase in demand of electricity its generation in huge amount has also become very important. In today's era, electricity is generated by burning the fossil fuels, but these fossil fuels will soon get depleted and this critical situation gives rise to the use of renewable sources of energy for generation of electricity. The main objective of the attempt is to produce electricity by using the force of air created by the moving vehicle on highways. On highways the vehicles face the problem while travelling at night due to less lightning. This problem can be overcome by using the vertical axis wind turbine (VAWT). This is one of the methods of power generation. Wind exerts force on the blade and this force will rotate the vertical turbine blade and this blade is coupled with the generator through shaft and this generator will produce electricity. Wind is an unconventional source of energy, by which the electricity can be obtained by converting kinetic energy of wind into electrical energy by using wind turbine.**

The current attempt describes vertical axis wind turbine and its importance in energy production. This attempt describes briefly the design consideration of vertical axis wind turbine with the aim to start or work in very low speed of wind. The model has been develop and fabricated. The aim is to make vertical axis wind turbine which can be installed at rural areas where electricity crises is the main problem. The effort has been taken to design the VAWT which can work at very low wind speed of 1-1.5 m/s.

Hence in the current attempt, the property of magnets that like poles of different magnet repel other and unlike poles attracts each other is taken into consideration. This attraction-repulsion property gives the good starting torque so that the turbine will tend to rotate continuously [13].

Keywords – Vertical axis wind turbine, guide blades, repulsion force,

I. INTRODUCTION

Wind is generated from solar energy by uneven heating of the earth. This uneven heating creates pressure difference in the atmosphere, generating wind. This wind can then be harnessed by a wind turbine. As the wind pushes the blades of a turbine, a generator attached to the axis of the shaft and when spun creates electricity that can be sent to the grid and used in households for electricity.

In this 21st century there are more methods to produce energy. Some of them are eco-friendly and some of them cause pollution. In order to produce energy by eco-friendly means, the best idea is by using renewable energy. In renewable energy field sector the wind turbine plays an important role in energy production. The current attempt deals with use of vertical axis wind turbine to generate the electricity as form of energy with some attachments [8].

II. PRINCIPLES OF WIND ENERGY CONVERSION

The main principle of vertical axis wind turbine is to convert kinetic energy of flowing wind into mechanical energy of rotation of blade or shaft. The flowing wind imparts force on turbine blades in the direction of wind flow. This force depends upon the wind speed, more the wind speed more is the force of impact. This force generates couple on the turbine. Once, this couple overcomes mechanical resistance of turbine, the turbine starts rotating. This rotation of turbine can be utilized for generation of electricity by connecting generator to shaft of turbine.

III. AIM AND OBJECTIVES OF PROJECT

The main aim of this project is to produce energy by using renewable energy resources, as the non renewable energy resources will get exhausted in a mere time if overuse today. This concern for the environment is the basis for the current attempt. The wind is eco-friendly and abundantly available resource. By using that energy in a useful manner a continuous power can be produced. This VAWT is a method which overcomes the previous wind turbine problems, by adjusting the wind flows on blades which suit itself with efficient energy generation in all direction.

Ultimate design aims of the current attempt are,

1. To reduce the self starting wind speed.
2. To improve the speed of rotation of turbine.
3. To keep turbine in continuous rotation even in the less wind speed.

IV. REVIEW OF LITERATURE

Nilesh N. Sorte & S. M. Shiekh dealt with the design and development of micro vertical axis wind turbine for rural application. This paper explains the various design parameters like swept area, number of blades, tip speed ratio, power coefficient and blade chord of micro vertical axis wind turbine along with their formulas. This paper also gives the idea about how to make the model of the prototype by using computer aided design software. Hence, this research paper helped in fulfilling few basic requirements of our project [4]. S.V.Saravanan, M. Varatharaj, L. Ayyadurai, S. Palani & D. Prem worked together and published a research paper which deals with the design and fabrication of vertical axis highway windmill. This research paper gives the design methodology for blades so that the efficiency of the wind turbine is increased. This paper gives the idea of shape of blade, tower height and design of blade etc. Hence, this research paper suggested the various parameters required for the blades, which is the center of attention of our project. This also gave us the idea about the application of our project that is; if our turbine is mounted near to the dividers of the highways then it can generate electricity by using the wind which blows as the vehicle passes on the highways [2]. Dinesh N. Nagarkar & Dr. Z. J. Khan told about the concept of magnetic levitation. It deals with the explanation of working of wind power plant using magnetic levitation wind turbine. In this paper the complete construction and working of wind power plant with magnetic levitation is given. But, in our project this magnetic levitation concept is not used. We have just use the concept of magnetic repulsion to reduce the self starting wind speed and to improve the speed of rotation of the turbine which in turn will keep the turbine continuously in rotation even with less speed [5].

V. DESIGN PARAMETERS FOR WIND TURBINE

V.1. Fixation of variables

1. Length of blades OR turbine, L = 900mm (Effective)
2. Diameter of turbine, D = 700mm
3. Clearance between turbine and casing disc = 20mm (Radial)
4. Casing disc dimension

   Inner diameter = 740mm

   Outer diameter = 1040mm
5. Diameter of semi-circular turbine blades, d_b= 153mm
6. No. of turbine blades = 6
7. No. of casing/guide blades = 6

V.2. Swept area [4]

The swept area is the section of air that encloses the turbine in its movement, the shape of the swept area depends on the rotor configuration. In this way the swept area of a straight-bladed vertical axis wind turbine the swept area has a rectangular shape and is calculated using:

$$S = 2\,RL \qquad (1)$$
$$= 2\text{x}0.35\text{x}0.9$$
$$= 0.63\text{m}^2$$

Where, S is the swept area [m^2], R is the rotor radius [m], and L is the blade length [m]. The swept area limits the volume of air passing by the turbine. The rotor converts the energy contained in the wind in rotational movement so as bigger the area, bigger power output in the same wind conditions.

V.3. Power and power coefficient [4]

The power available from wind for a vertical axis wind turbine can be found from the following formula:

$$P_w = \tfrac{1}{2}\,\rho\, S\, V_o^3 \qquad (2)$$

Where, V_o is the velocity of the wind [m/s] and ρ is the air density [kg/m^3], the reference density used its standard sea level value (1.225 kg/m^3 at 15ºC). Note that available power is dependent on the cube of the airspeed. The power the turbine takes from wind is calculated using the power coefficient:

$$C_p = \frac{\text{Captured mechanical power by blade}}{\text{Available power in wind}} \qquad \ldots(3)$$

Cp value represents the part of the total available power that is actually taken from wind, which can be understood as its efficiency.

The theoretical calculation for 6 m/s wind is as follows;

$$P_w = \tfrac{1}{2}\,\rho\, S\, V_o^3$$
$$= 1/2\text{x}1.225\text{x}0.63\text{x}6^3$$
$$P_w = 83.249 \text{ watt}$$

Hence from above Power available (P_w) at 6m/s we get the output of 83.249watt. Considering the efficiency of 16.67%, the power captured as 13.894watt.

For 10m/s,

$$P_w = \tfrac{1}{2}\,\rho\, S\, V_o^3$$
$$= 1/2\text{x } 1.225\text{X}0.63\text{x } 10^3$$
$$P_w = 385.875 \text{ watt}$$

Again considering efficiency of 15-20%, the power captured is 64 watt approximately.

V.4. Tip Speed Ratio [4]

The power coefficient is strongly dependent on tip speed ratio, defined as the ratio between the tangential speed at blade tip and the actual wind speed.

$$TSR = \frac{\text{Tangential speed at blade}}{\text{Actual wind speed}} = \frac{R\,\omega}{V_o} \qquad (4)$$

Where, ω is the angular speed [rad/s], R the rotor radius [m] and V_o the ambient wind speed [m/s]. Each rotor design has an optimal tip speed ratio at which the maximum power extraction is achieved.

V.5. Blade chord [4]

The chord is the length between leading edge and trailing edge of the blade profile.

Blade cord, c = .153m

V.6. Number of blades [4]

The number of blades has a direct effect in the smoothness of rotor operation as they can compensate cycled aerodynamic loads. For easiness of building, six blades have been used. The solidity σ is defined as the ratio between the total blade area and the projected turbine area. It is an important non-dimensional parameter which affects self-starting capabilities and for straight bladed VAWTs is calculated,

$$\sigma = Nc/R \qquad (5)$$
$$= 6\text{x}153/700$$
$$= 1.31$$

Where, N is the number of blades, c is the blade chord, L is the blade length and S is the swept area, it is considered that each blade sweeps the area twice. Solidity determines when the assumptions of the momentum

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models are applicable, and only when using high $\sigma \geq 0.4$, a self starting turbine is achieved. In this project with contemplating six blades solidity of 1.31 has been considered for self starting property of the project.

VI. WORKING OF WIND TURBINE

The working of vertical axis wind turbine is simple. Whenever wind flow though the turbine blades, it exerts some force on the blades. This imparts the movement of blades in the direction of wind flow, which ultimately results in the rotation of turbine.

As our vertical axis wind turbine comprises of guide blades and magnets to create repulsion force in the direction of rotation of turbine, these gives benefits in the performance.

When wind flows to the turbine, first it has to flow through the casing. As the casing blades are kept 30^0 inclined to the tangent drawn to inner diameter of casing disc, they direct the wind directly to the turbine blades. This gives better impact of wind on turbine blades which results in increasing the applied force by wind on the turbine blades and hence torque has also increased. In the mean time, it helps to increase the speed of wind flow.

In the current attempt, the magnets are used. Magnets are arranged at 30^0 inclined to tangents of inner circle of casing as well as turbine circle both. Magnets are placed on turbine outer and casing inner circle in such way that same poles of magnets are always facing each other. This creates the repulsion force in the direction of rotation of turbine. Due to this force, the turbine rotates or tends to rotate. This repulsion force also reduces the force required to start the rotation of turbine further. Hence, the wind speed required for self starting of turbine gets lowered.

In this way, casing guide blades and magnetic repulsion helps turbine to rotate at faster speed and with less self starting wind speed as compared to other normal turbine.

This rotational motion of turbine can be used for electricity generation if generator is coupled to the shaft.

VII. SELECTION OF MATERIAL

Sr. No.	Component and specification	Material
1.	Shaft (0.02 m dia.), threading (0.12 m)	Mild steel
2.	Turbine disc (0.012 m thick)	Plywood
3.	Casing ring (0.012 m thick)	Plywood
4.	Shaft nut (M 24)	Mild steel
5.	Casing support	Mild steel Angles
6.	Turbine blades (.153 m dia.)	Bore well PVC pipe
7.	Casing blades (0.01 m thick)	M.D.F.
8.	Turbine blades strip	Mild steel
9.	Wooden bead strips (0.01x0.01 m)	wood
10.	Shaft washers	Mild Steel
11.	Bottom support	Mild steel rod
12.	Magnets	Ferrite magnets
13.	Tapered roller bearings	Stainless Steel

VIII. DEIGN OF TURBINE BLADES

As the attempt was done to design the turbine for maximum wind speed of 10 m/s, hence maximum power it can produce is, P_{max} = 385.875 watt.

Maximum torque to which turbine will subjected is,

$T_{max} = P_{max}/\_\omega = P_{max} /(V/R)$ (6)

Where, ω = Angular speed of turbine blades [rad/s]

V = linear velocity of blades at the tip

R = radius of turbine

Considering tip-speed ratio to be 2, then linear velocity at the tip is 5m/s.

$T_{max}= P_{max} /(V/R)$

$= 385.875/(5/.35)$

$T_{max} = 27.01125$ Nm

Maximum force acting on blades,

$F_{max} = T_{max} /R = 27.01125/.35$ (7)

$F_{max} = 77.175$ N

For good lift force and minimize the drag force, angle of attack should be in between 30^0-45^0. In our case, this is taken care by guide blades on casing. [1]

The turbine blades are made up of PVC pipes which were cut in semi-circular shape to serve the purpose.

Angle of attack = 30^0

Lift = $77.175\cos(30^0) = 66.835$ N (8)

Drag = $77.175\sin(30^0) = 38.587$ N (9)

Collapse resistance of blades = 735.75 kPa… (From Std. catalogue of PVC pipe)

Blade strength = F_{max} /Area of single blade (10)

$= 77.175/(\pi d_b^2 L/4)$

$= 77.175/(\pi x.153^2 x.9/4)$

= 4664.0305 Pa < collapse resistance of blade

Hence, design of blades is safe.

IX. SIGNIFICANCE OF MAGNETS

As magnets are arranged in such a manner that they will repel each other. Magnets on turbine and casing are arranged at 60^0.

Force acting on blades at wind speed of 3m/s without magnets,

F = 10.206 N…. (As per calculations done in design of turbine blades)

Force exerted by individual magnet pair

= 0.054cos(60) = .027kg = .264N

Fig.1- Magnetic arrangement

The calculation for magnetic repulsion force is done by online on the site "ADAM's MAGNETIC PRODUCTS".

Total force by 12 pairs of magnets = 3.178 N

Reduced force required for turbine
= 10.206 - 3.178 = 7.028N

Reduced air velocity required for turbine for force of 7.028 N = 2.63m/s, which is less than 3m/s.

This shows that magnets reduce the required speed for rotation of turbine (self-starting speed).

X. TESTING AND RESULTS

1. Testing

The attempt was carried on the turbine for analyzing purpose. Speed of turbine is measured in rpm for different velocities of wind in m/s. Also test had been carried out when blades are present and when casing blades are not present.

Speed is measured for same flow at different location of turbine facing wind flow. The following results are found for the testing.

Wind velocities at different location points on the turbine, m/s				Average wind speed, m/s	Speed of turbine, rpm	
V_1	V_2	V_3	V_4		Without guide blades	With guide blades
0	0	0	0	0	0	0
0.2	0.3	0.5	0.3	0.325	0	0
0.5	0.7	0.9	0.8	0.725	0	0
0.8	1.1	1.3	1.1	1.075	18.1	20.2
1.3	1.6	2.2	1	1.525	20.8	23.1
1.6	1.8	1.6	0.8	1.45	23.7	27.4
1.1	2.9	1.7	2.5	2.05	31.2	38.7
3.3	3.5	3.2	2	3	38.5	46.3
2.3	4.9	5.3	4.5	4.25	48.2	58.3
5.5	5.7	5.5	7.5	6.05	83.7	98.9

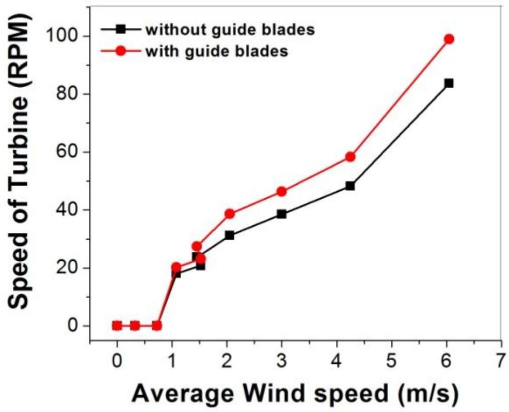

Fig.2- Speed behavior of turbine with wind speed

2. Results

The results are shown in above graph. In testing, the self-starting speed of turbine is obtained as 1.08 m/s. It is clearly shown from graph, the speed of turbine is also increased due to the use of guide blades and it also gives better impact on turbine blades. Also, once turbine starts rotating, it rotates continuously at wind speed less than self stating speed required.

XI. CONCLUSION

In the current attempt, solidity, number of blade, chord length of blade etc. are the basic design consideration for design and development. After the input design parameters, the conceptual model was designed in Creo software.

All the efforts were made to develop the model which can generate the output even at low wind speed. Parts were developed and fabricated with light materials. The magnets are used to increase the starting torque by using the repulsive force. Finally, the testing of the model was the main area towards the success of project and outcome of the project of input decided while designing and development of the product.

In the current attempt, self-starting speed is of 1.08 m/s, which is much lower. Also turbine is in motion once it starts even after the speed is less than 1.08 m/s. This is due to the repulsive force of magnets used.

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Fig.3- Raw model

Fig.4- Final model

XII. FUTURE SCOPE

If large scale maglev wind turbines can supply vast amount of electricity at economic cost then the advance of maglev wind turbine is a very timely developed. It plays a major role in the development of world. Magnetic levitation is an important development to reduce stress from the mechanical load on the wind turbine. There is huge scope of modification in the design of guide blades, their angles etc.

Some of the future modifications are as follow;

1. Optimizing the design of blades so as to give smoother impact.
2. Using a best alternator which produces more voltage for low rpm.
3. Using gear mechanisms to increase rpm for alternator input and hence can have higher power output.
4. Structural fabrication can be modified for vibration reduction and optimizing the performance.
5. Using fixed base system to reduce the weight of the whole system.
6. Modifying the turbine for gearless power generation by increasing its diameter.

XIII. REFERENCES

[1] Bitubishop Deori, Subroto Barman, Suraz Das, Mukhtar Hussain, Sachi Mohan Basumatary and Kaushal Kumar Sharma,"Experimental study on the performance of Lenz vertical axis Wind Turbine", Journal of Material Science and Mechanical Engineering (JMSME), Volume 2(9), 2015, pp. 62-64

[2] S.V.Saravanan, M. Varatharaj, L. Ayyadurai, S. Palani & D. Prem, "Design and fabrication of vertical axis highway windmill", International Journal of Advanced Electrical and Electronics Engineering (IJAEEE), Volume-2(2), 2013, page no. 2278-8948

[3] Raciti Castelli, M., Englaro, A., Benini, E., "The Darrieus wind turbine: Proposal for a new performance prediction model based on CFD", Volume 36, 2011, pp. 4919-4934

[4] Nilesh N Sorte, S. M. Sheikh, "Design and development of micro vertical axis wind turbine for rural application", International Journal of Engineering and Computer Science, Volume 03 (07), 2014, pp. 7035-7040.

[5] Dinesh N. Nagarkar & Dr. Z. J. Khan, "International journal of engineering and innovative technology", Volume 3(01), 2013, pp. 324-326.

[6] Pravesh K. Sahare, Tanveer A. Hussain, Sangita N. Kakde, Sujata R. Ingle, Ambikaprasad O. Chaubey, "Review Paper on Vertical Axis Maglev Wind Turbine", International Journal of Research in Mechanical Engineering & Technology, Volume 6(1), 2016, pp. 76-79

[7] Selvam, M., Ramesh, R., Palanisamy, R., Mohan, A. and Muthu Manokar, A., "Design and Analysis Of Vertical Axis Wind Turbine", International Journal of Development Research, Volume. 4(2), 2014, pp. 313-315

[8] The Hitvada(03/2017), the data written in the need of the project was taken from the article of the Hitvada under the heading use of "Renewable source of energy is the need of an hour".

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 05, May - 2017

[9] Magedi Moh. M. Saad, Norzelawati Asmuin, “Comparison of Horizontal Axis Wind Turbines and Vertical Axis Wind Turbines”, International organization of Scientific Research, Volume 4(8), 2014, pp. 27-30

[10] Swapnil.J.Bhadang, Prof. Atul.S.Tumane, “Design, Analysis & Power Generation through Axis

[11] Wind Turbine”, International Journal for Research in Applied Science & Engineering Technology, Volume 2(11), 2014, pp. 316-320

[12] Niranjana.S.J, “Power Generation by Vertical Axis Wind Turbine”, International Journal of Emerging Research in Management &Technology, Volume 4(7),2015, pp. 1-7

[13] Louis Angelo Danao, Jonathan Edwards, Okeoghene Eboibi, Robert Howell, “The Performance of a Vertical Axis Wind Turbine in Fluctuating Wind – A Numerical Study”, Proceedings of the World Congress on Engineering 2013, volume 3, 2013

[14] Sharangdhar Dehadrai, Anurag Wasnik, Yogesh Gaidhane, “Study on Magnetic Levitation for Vertical Axis Wind Turbine and Low Wind Speed”, International Journal of Science Technology & Engineering, Volume 2(10), 2016, pp. 459-464

[15] Sunil Shukla, P. K. Sharma, Suryabhan A. Patil, “A Review Paper on Vertical Axis Wind Turbine for Design and Performance Study to Generate Electricity on Highway”, International Journal of Advance Engineering and Research Development, Volume 3(12), 2016, pp. 116-122