

Design and Fabrication of Multi-Rotor Horizontal Axis Wind Turbine

J.Jayapriya, D.Muruganandam, D.Raguraman, B.Senthilkumar, V.Dhinakaran



Abstract: Wind is an endless resource which is abundantly found in nature. Harnessing wind energy for producing electricity is one of the ways for buildings for a sustainable future. Small-scale wind turbines could be a reliable energy source for usage in homes and in autonomous applications in locations that are far away from the grid power. Small wind turbines operating at low wind speeds regularly face the problem of poor performance due to small rotor size. To increase the power production additional wind turbines are installed. This increases the overall cost of the project. To reduce the cost and to improve the efficiency, multiple rotors are connected through a single shaft to the fixed single generator. The Implementation of this design permits start up at lower wind speeds, increasing the start-up torque and thus improving the overall performance of the turbine. This paper elaborates the design and fabrication of such a wind turbine. [1] [2] [3]

Keywords: Small-Scale Wind Turbines, Multiple Rotors, Single Generator, Low Wind Speeds, Community wind turbines, Green Energy.

I. INTRODUCTION

Nowadays producing carbon free electricity is the major challenge in this world with the advent of climate change and depletion of fuels. In the present scenario of steadily rising electrical costs, installation of wind turbines at the roofs of homes has the potential to reduce energy demand from the grid. With the installation of right capacity wind energy system at homes everyone can become energy independent. [4]

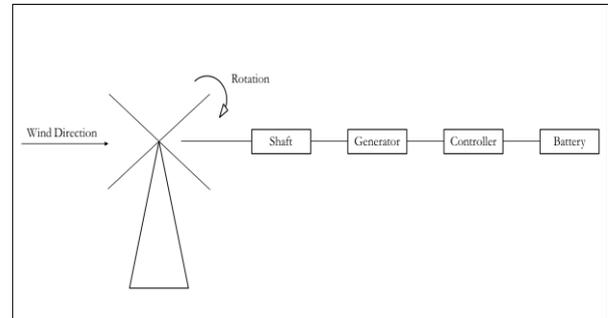


Fig.1 Wind turbine block diagram

Small-scale wind turbines can be installed in sites having restrictions in space. To ensure maximum extraction of power, the multi-rotor turbines have been designed and analyzed to suit the requirements of low wind areas. When wind turbines are placed at the place of consumption preferably on the building parapet walls of homes and offices, power loss due to transmission from grid can be reduced. The small-scale wind turbines generally consist of single rotor for each generator. A key change in this design is the incorporation of multiple rotors to a single generator. This eliminates the cost of additional generator for each added rotor. The major advantage of this design is the ability to connect any number of rotors to the single generator by increasing the length of the shaft. The present work elaborates the design and fabrication of such a wind turbine for home application. This research work is for generating electricity at low wind speeds which can be used to power the electrical requirements of a house. [3] [5]

II. EXPERIMENTAL WORK

The purpose of present research is to provide a low-cost solution for generating maximum power in low wind velocity sites through a single generator with the help of multiple rotors coupled to it by the extension of generator shaft. The design of the wind turbine should satisfy the following criteria: [6]

- Cost effectiveness
- Low maintenance
- Good lifetime
- Blade strength
- Less weight

To achieve the above mentioned, objective study work has been divided into five main parts:

- Design of Components
- Fabrication technique
- Experimental procedure
- Results and discussion

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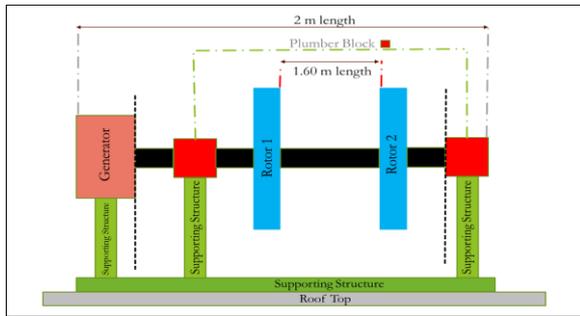


Fig. 2 Model Representation

III. WORKING PRINCIPLE

Wind turbines extract energy from the wind through aerodynamic forces converting kinetic energy into revolving energy through the rotation of shaft. The two major aerodynamic principle forces used are drag and lift. [7]

IV. DRAG DESIGN

Drag applies a force on the body in the direction of the relative flow. Thus, wind literally pushes the blades out of the way. This means that it is impossible for the turbine to rotate faster than the wind. Drag powered wind turbines are characterized by slower rotational speeds and high torque capabilities. The volume of material needed to build an air resistance wind turbine is much higher than for a lift turbine. This has negative consequences on the performance, cost and installation. It has been proven by theoretical analyses and field tests that air resistance wind turbines have a maximum efficiency of only 15% [8]

V. LIFT DESIGN

Lift applies a force on the body perpendicular to the relative flow. The lift blade designs employ the same principle that enables airplanes, kites and birds to fly. The blade is essentially an airfoil, or a wing. When air flows past the blade, a wind speed and pressure differential is created between the upper and lower blade surfaces. Pressure at the lower surface is greater and thus acts to "lift" the blade. These blades move at right angles to the wind direction, at a higher speed than the actual wind speed. When blades are attached to a central axis, like a wind turbine rotor, the lift is translated into rotational motion. The lift propelled turbine has high efficiency. The maximum efficiency is 59%, it also called the Betz limit. This is the maximum power that can be extracted from the wind. [9][10]

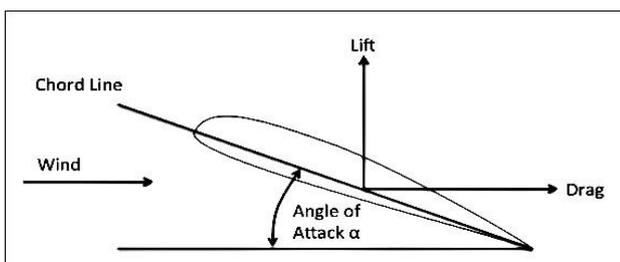


Fig.3 Principle of wind turbine aerodynamic lift

VI. DESIGN OF COMPONENTS

A. Blade

- In case of horizontal axis wind turbines which are of lift type, blades are installed to take advantage of lift forces. Increasing the number of blades increases the efficiency of the turbine. To archive maximum performance a five-blade design is selected. Thus, a total of ten blades is installed in two rotors.
- To avoid interference of wind flowing from one turbine to the other, the two rotors are placed at a minimum distance of 1.6 m. This enables the second rotor to receive fresh wind despite the wind striking the first rotor. Also, the rotors are angled in such a way that the blades of the second rotor fill the gap of first rotor. [3]
- To reduce the weight of the blades composite material, Glass Fiber Reinforced Polypropylene (FRP) has been used for the fabrication of blades. This has contributed to a low rotational inertia, which means that the wind turbine can accelerate quickly if the winds pick up at higher speeds. Also, using glass fiber reinforced plastics for the fabrication; the blades can be easily be molded to the required shape. Besides, fiber glass provides the required stiffness for the blades. [6] [11].
- The blade length is considered as per the designed power output. For this, project a blade length of 425mm has been used. The hub diameter is 150 mm. Thus, the overall diameter of the turbine is 1000 mm.



Fig. 4 Fiber Reinforced Plastic (FRP) Blade

B. Height

The velocity of wind increases at higher altitudes hence it is ideal to place the wind turbine on the roof top of home and commercial buildings. Atypical two-story building has a height of seven meters. This provides moderate wind speeds which is enough to operate the small wind turbine.

C. Tower

- The tower is the frame or supporting structure on which the turbine and generator assembly is mounted. The tower also provides the necessary elevation for the turbine blades to clear the ground. Also, the tower height can be increased to keep the turbine in strong winds.
- It must be noted that the tower must be placed away from obstructions as it causes turbulence and thus drastically reducing power output. [12]

- The tower has been constructed using steel. Rectangular cross-section tube is used for the base while L-angle is used for raising the tower height. It is on the L-angle where the linear shaft which houses the generator and turbine are mounted with the help of a Plummer block. Using channel for base and L-angle for raising tower height ensures that the frame is heavier at the bottom, lowering the center of gravity. Steel material is used as it costs less, and it provides the necessary weight for the base to ensure the stability of structure under high wind speeds.
- In this fabrication project the tower has been raised to a height of one meter. Thus, the turbine is kept at an overall height of eight meter which is approximately equal to 26 feet. [12]

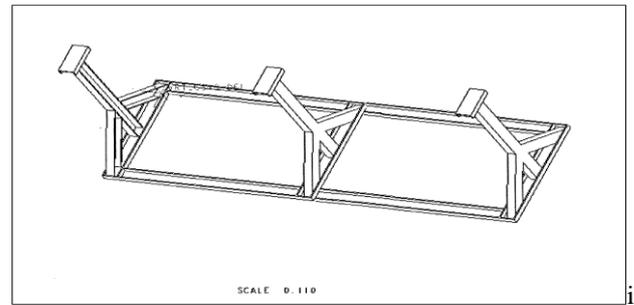


Fig. 5 Frame for mounting the Turbines

D. Generators

Generators are available in large output ratings. A generator is selected after calculation of design power output of wind turbine which is proportional to the length of the blades. Longer the blades greater is the power output.

Table 1 – Materials used for the fabrication

	Product	Specification	Quantity	weight(kg)	cost/kg	cost/piece	Total cost in rupees
1	MS Channel	75 X 50 X 6 mm	13000mm length	92.86	45.5		4224
2	Bright Flat	25 x 3 mm	1500mm length	0.88	60		53
3	Bright Flat	25 x 8 mm	750mm length	1.18	60		71
4	Bright Rod	25mm dia	2200mm length	8.48	55		467
5	MS Rod	50mm dia	100mm length	0.77	50		58
6	MS Circular Disk	150mm dia	15mm thick	4.16	60		250
7	Pillar Type Plumber Block	25mm Inner dia	3 pieces			205	615
8	Glass FRP Blade	435mm length	10 pieces			2000	20000
9	DC PMG	12v 300w 600rpm	1 unit			11800	11800
10	Battery	12v 42AH	2 unit			4000	8000
11	Charge Controller	12v 20A	1 unit			1300	1300

Generators are broadly classified into AC and DC generator under these categories there are various types which differ in output specification and efficiency. A generator is chosen after considering the intended use. An AC generator is used for powering AC appliances it has output of either 120V or 240V at 50 or 60 hertz. While a DC generator is used for powering DC appliances it has output of either 12V or 24V. The power output from generator varies as the wind speed changes hence a charge controller is connected to the generator which stabilizes the output current. Since it is desired to store the electricity for use when wind speed drops drastically. So, a DC generator has been selected. As for storing electricity only DC battery is available. If required, the DC current from the battery can be converted to AC with the help of DC to AC inverter. There are various types of DC generator such as car generator has efficiency of 50%, induction generator which has efficiency of 80% and permanent magnet generator which has efficiency of 78%. Considering optimum performance, low cost and maintenance a 12v permanent magnet generator of 250W is selected based on design power output. [13]

A. Battery

The load is a television which need 12V and 120W power. It will be used of 5 hours a day. Considering worst case situation, the required battery capacity is (120W) (5 h) / 12V

= 50Ah. To ensure long battery life, the ideal percentage use of battery is 60%. Thus, battery capacity is: 50Ah / 60% = 83Ah. The 83Ah battery can be obtained by connecting two 42Ah battery in parallel. [14]

B. Charge controller

A charge controller is connected intermediate to the generator and the battery. Its function is to provide a stable 12V current to the battery by converting the fluctuating voltage from the generator. The charge controller also monitors the battery voltage to prevent overcharging and over discharging. The charge controller uses pulse width modulation to regulate the current flow in and out of the battery. Whenever the battery voltage reaches 16V charging is stopped. Also, when the battery voltage drops to 10.8V discharging to the load is stopped. The charge controller also protects the battery from high voltage during high wind speeds. [15]. Table 1 shows the details of the materials used for the fabrication.

VII. RESULTS AND DISCUSSIONS



Fig. 6 Multi-Rotor Wind Turbine

Calculation of wind power & Field Testing [1] [2] [5]

Power in the area swept by the wind turbine rotor:

$$P = \frac{1}{2} * \rho * A * C_p * v^3 * n$$

Where:

P = power in watts

ρ = air density (about 1.1455 kg/m³ at 35c)

A = rotor swept area, exposed to the wind = πR^2

(Swept radius R= 0.5 m)

C_p = Coefficient of performance (.59 {Betz limit} is the

Maximum theoretically possible, .35 for a good design)

V = wind speed in m/s (7.5m/s is the maximum recorded wind

Speed in our area)

n = number of rotors

Table 2 shows the power output measured from the turbine.

Table 2 Wind Velocity vs RPM vs Power

wind velocity (m/s)	rpm	Power (w)
4	30	15
5.8	90	50
7.5	300	150

A 12v 300W 600rpm permanent magnet generator is used for Power generation.

VIII. CONCLUSION

Hence it can be seen that when multiple rotors are added to a linear shaft for a given rotor diameter, the power output is a multiple of number of rotors. The multi rotor design can be used for increasing the power production in location where there are space restrictions. The key advantage of multirotor design is that, when the rotors are added the torque is multiplied however the speed remains the same this enables a safer wind turbine which is suitable for homes. [2]

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