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Experimental setup of micro wind turbine

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ABSTRACT

The exhaustion of fossil fuels, spreading global warming, higher need of energy and lack of power supplies leads to the use renewable source of energy like wind-energy. Although there are abundant of wind energy available in many regions in our country, the application of wind turbines to harness power efficiently is very limited. The primary objective of this project is to study fabrication of windmill, study and analyze the results and to use them in various applications like automobiles, top storey buildings, coastal areas and boats. Also to analyze the output generation on different environmental conditions like wind speed, air density, etc. Simulation, theoretical and experimental methods will be used. In experimental methods direct results will be analyzed from the experimental setup of the turbine. In simulated methods software like ansys will be used to calculate the fluid flow, structural data etc. And in theoretical method calculation of the expected power will be done using theoretical formulas. The research also focuses on selection of wind turbine and selection of its components like generator, material selection, etc. For that a market survey is important to minimize the cost and increase the effectiveness of the wind turbine. The market survey can be done in two types offline market survey like visiting local shops and industries and online market survey which can be done using Google, amazon etc. The expected outcome is to generate power of range 50-100 W. For this research blades with different materials were used to test the effectiveness of the turbine. Along with that different types of motors were used as a generator for testing. A power of minimum 10 W and maximum 50 W was produced. This research also focused on the cost effectiveness of the turbine. It was manufactured in 6000 INR.

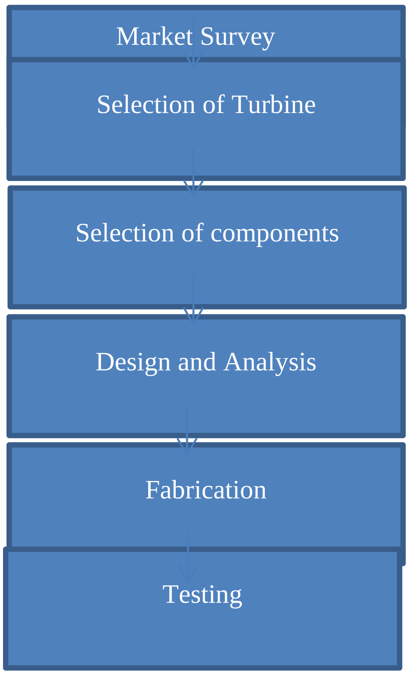
Keywords: *Windmill, Applications, Wind Turbine, Generator, Rotor Blades, Sustainable Energy, Renewable Energy, Renewable Resources*

1. INTRODUCTION

Wind Turbine is a device which converts wind's kinetic energy into electrical energy. Wind turbine is important source of renewable energy and due to exhaustion of fossil fuels the demand is increasing rapidly. It has the most favorable social impacts compared to other sources of energy which includes less greenhouse gas emissions, water consumption demands etc. There are different types of wind turbines like micro, mini and large. Micro and mini turbines can be used for smaller applications like battery charging, light a bulb, warning signs etc. , while larger turbines can be used domestic power supply.

Although it has many applications and uses, along with that it has some limitations which cannot be neglected. For instance, setup of a wind farm is completely dependent on the geographical locations as it requires lot of wind with a speed of minimum 6 m/s. Also it is not a completely cost effective solution. Setup of a wind turbine requires huge investment and maintenance for large scale as well as small scale turbines. Whereas, the return on investments is comparatively less. Hence this research paper focuses on the cost effectiveness of small scale wind turbine as well as testing them on different applications. Therefore, to make a cost effective wind turbine a market survey is necessary to select rotor blades and its material, generator, etc. Also analysis of rotor blades is also necessary while selecting them.

2. METHODOLOGY



3. MARKET SURVEY

Market survey is one of the important factors while designing and fabricating of any product. It helps for costing of the product and helps to explore different options available in the market. The market survey was done in both online and offline methods like local vendors, amazon and industries. In this research our objective was to identify and select a suitable generator and rotor blades. The types of generators identified AC generators, DC generators, DC motors and synchronous motors. The industries we contacted were tachometric controls, synchrotech, MICA engineers, etc. The cost of generators for 50-100 W output was approximately 9000-13000 INR while, on the other hand the cost of DC and synchronous motors was comparatively less and was around 1000-2000 INR.

Fig 1: AC motor

Fig 2: Permanent magnet motor

Apart from that a survey for rotor blades was also necessary for selection of material and size. Industries which were contacted for selection of rotor blades were Om Industries, Autodynamic Engineering Private Limited, Tirumala Services, etc. From that research it was observed that the material commonly used for manufacturing of rotor blades were. PVC, GI sheet, aluminium sheet and carbon fibre.

4. SELECTION OF TURBINE

Wind turbine can be classified into two types on the basis of the axis of their rotation. First is the horizontal axis wind turbine (HAWT) and another one is the vertical axis wind turbine (VAWT). Further VAWT is divided into two categories i.e darrieus wind turbine and savonius wind turbine. In HAWTs, the rotating axis of the blades is parallel to the direction of the wind. In VAWT, on the other hand, has the axis of the drive shaft is perpendicular to the ground. HAWT are unidirectional but by adding yaw mechanism it can accept air from all other dirctions while VAWT are Omni directional.

The turbine selected for this research was horizontal axis wind turbine. There were various reasons for selection of this turbine out of which the main reason was the efficiency of this turbine. The efficiency of HAWT is more than VAWT and more power generation. Apart from those other factors like area swept was more in HAWT, self-starting, fabrication and structure is less complex compared to VAWT etc. A basic CAD model was drawn using solidworks of HAWT. However according to the availability of resources some modifications were made while fabrication.

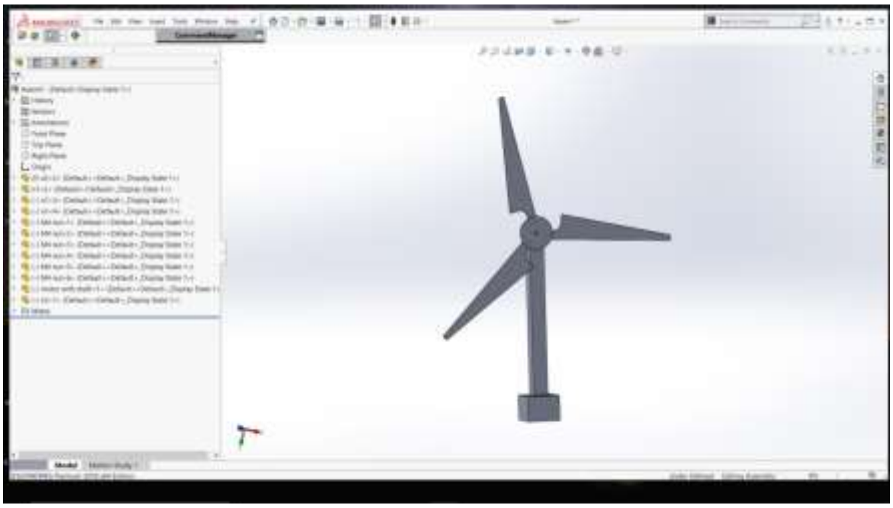


Fig 3: HAWT CAD Model

Basic Model for Wind Turbine

A small model of wind turbine was made using an AC submersible water pump. A motor of 18 W was used as a generator. Also a fan of air cooler was used as rotor blades and a bridge rectifier was used to convert the AC into DC. 2W of power was generated from this basic model which is not sufficient to operate on different applications.

5. CALCULATIONS

Power = 0.1* velocity^3* diameter^2
Velocity= 5m/s
Diameter= 0.5 m
Power= 0.1*0.5^2*5^3
Power= 0.1*0.25*125
Power is approximately 3W

Fig 4: Basic Model of Wind Turbine

6. SELECTION OF COMPONENTS

Generator

Selection of generator is the important factor for the wind turbine as it converts mechanical rotational power produced by the wind energy into electrical energy. Due to high cost of the generator synchronous motors were used in this research as a generator. These motors are usually used as a generator. These generators are appropriate for variable speed operation. Due to this it will generate variable voltage and variable power at variable speed. The synchronous motor selected was reversible low speed synchronous motors. The specifications of this motor are given in the below table.

Table-1: Generator Specifications

MOTOR SPECIFICATIONS	UNITS
Current	0.15 A
Voltage	240 V
Maximum output	36 W
RPM	60
Torque	10 kg.cm

Fig 5: Generator

Bridge Rectifier

A bridge rectifier is an essential component of a wind turbine. It can convert AC generated into DC which can be further used for several applications. Bridge rectifier is DIY device and can be made from diodes and capacitors by connecting them. Circuit diagram of bridge rectifier is shown below.

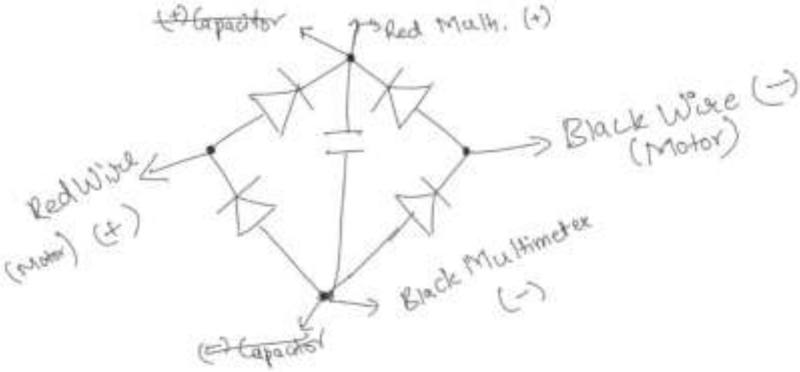


Fig 6: Bridge Rectifier

Selection Of Blades

Rotor blades are also an important part of the wind turbine as they decide the performance of the turbine. The length of the rotor blade is decides the power generation in any wind turbine as the more area swept, more the performance of the turbine. Blades of wind turbine are divided into two types, flat and curved. Flat rotor blades are cheap and easy to cut and have a consistent shape and size. The design and construction is simple and easy but the efficiency of these blades is less. While on the other hand the curved blades move faster than flat blades which results in generation of more power. Therefore to increase the efficiency of the turbine it is necessary to give an aerodynamic shape to the blade to provide lift and rotation of the blade. The length of the blade selected is 0.7m and thickness of 4mm.

Along with that selection of material of blades is also important as properties of the material helps to rotate the blades. These properties help the rotation of blade at lower properties. The factors required for blades are flexibility, strength and light weight. The more the blade is light weight, more it will rotate faster. But along with that the strength of the material should be more to resist the air pressure. Usually carbon fiber, PVC, GI sheet, Fiber glass is used for making of rotor blades. CAD model of blade is shown below.

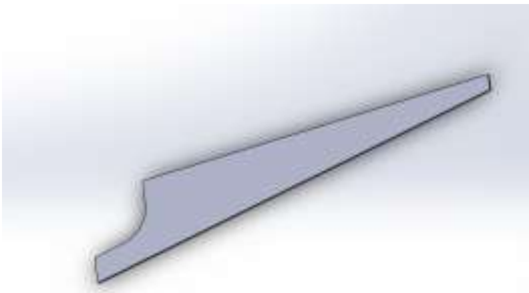


Fig 7: Rotor Blade

7. SIMULATION AND ANALYSIS

Matlab Simulation

A MATLAB simulation was performed on Simulink in which power and RPM can be found out by changing the blade length and wind velocity. It was derived from the formula of rated power output i.e. P = ½*p*A*v3*cp and RPM formula RPM= (TSR*60*v)/(pi*d). Here standard values were taken like tip speed ratio is 5 which are standard for 3 blade turbine, air density as 1.2kg/m^3 and cp was 0.45.

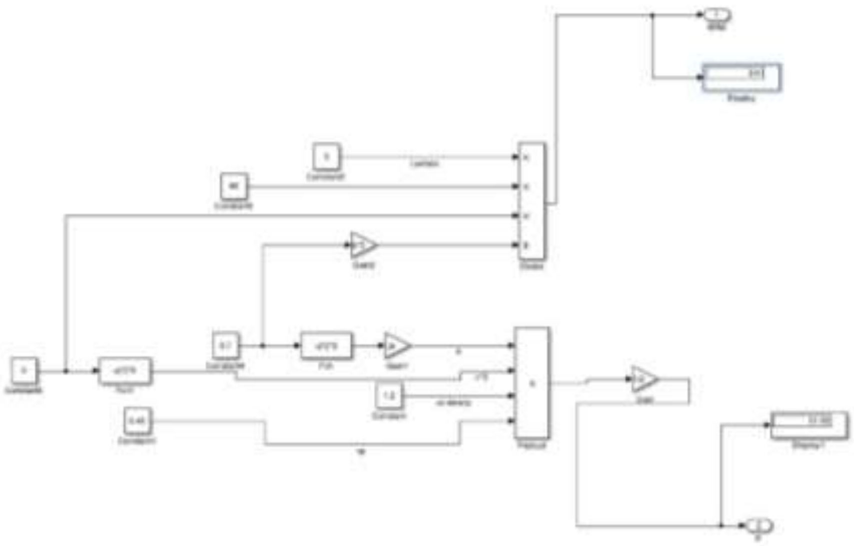


Fig 8: MATLAB Simulation

CFD Analysis

Computational fluid dynamics is used to study the analysis of fluid flow using numerical methods. In this research CFD was used to study the effect of wind flow at different wind speeds on the turbine. Factors like pressure, torque, force was calculated using the simulations on the turbine. Along with that flow trajectories are also drawn on the wind turbine.

Simulation AT 4 m/s Wind Speed

A simulation was performed with the velocity of wind at 4 m/s. From the flow trajectories it was observed that minimum pressure developed was 99443 Pa and maximum pressure developed was 103397 Pa. Rest of the factors are given in the table below.

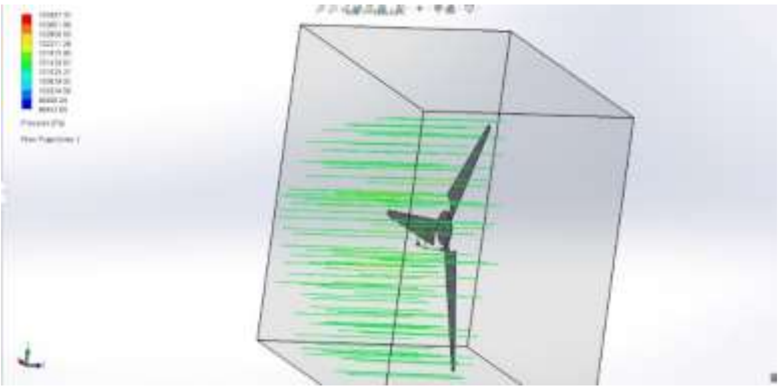


Fig 9: Flow Trajectories

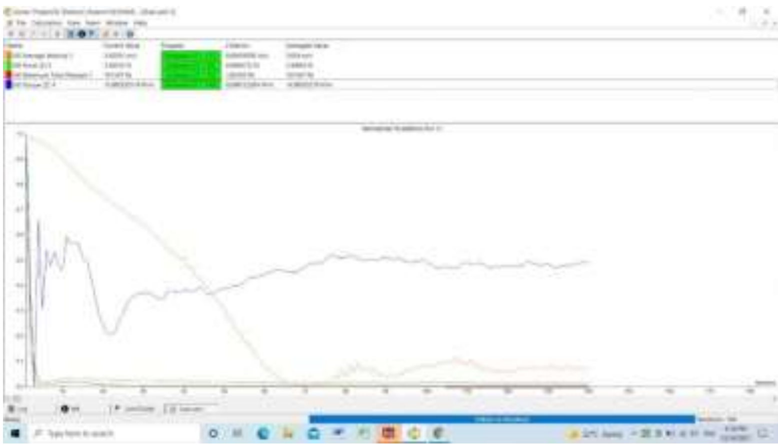


Fig 10: Graph for different parameters

Simulation AT 5 m/s Wind Speed

A simulation was performed with the velocity of wind at 5 m/s. From the flow trajectories it was observed that minimum pressure developed was 101281 Pa and maximum pressure developed was 103447 Pa. Rest of the factors are given in the table below.

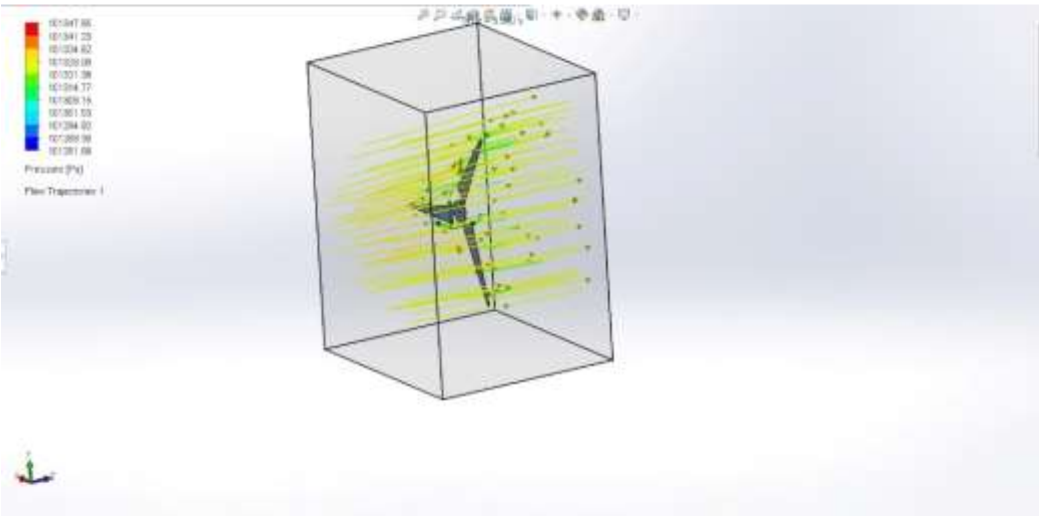


Fig 11: Flow Trajectories

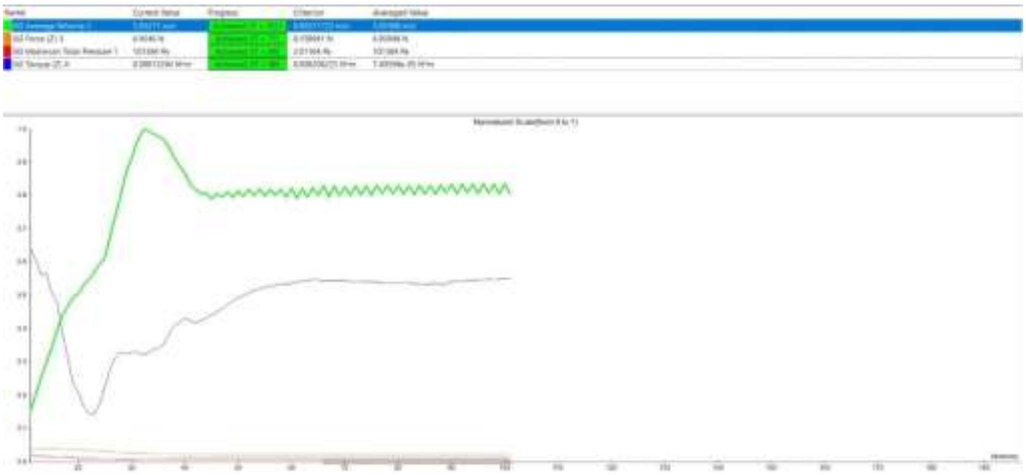


Fig 12: Graph for different parameters

8. SIMULATION RESULTS

Table 2: Simulation Results

Torque (N.m)	Avg Force (N)	Avg Pressure (Pa)	wind speed (m/s)
0.0125	2.112	101298	3
0.0352	3.366	101347	4
0.074	6.959	101384	5
0.101	10.157	101412	6

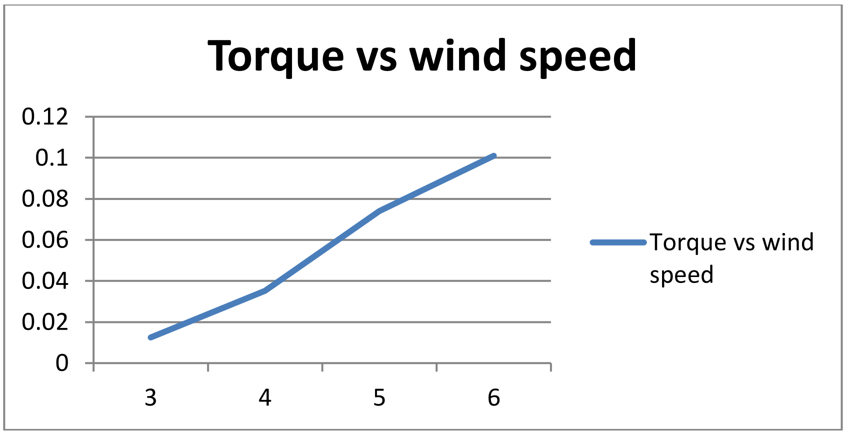


Fig 13: Graph torque vs wind speed

9. FINAL EXPERIMENTAL SETUP AND PROCEDURE

Fabrication of the turbine involved machining processes like welding, cutting, drilling and bending. Components used were square pipe of GI of 1.5 × 1.5 inch, rotor blades made up of two types Aluminium and GI sheet. Gears of bicycle were used to reduce the gear ratio of the turbine and bicycle body of MS and powdered coated was used as a support frame. The main shaft that connects the rotor blades is connected to gear with 50 teeth further it was connected to the shorter gear with a chain drive. Also a pulley was used which is fixed on the shaft of the motor. The pulley was connected to the shorter gear through a belt drive. Cutting and bending was used in fabrication of blades. Cutting was used to cut the blades from the GI sheet and FRP. After that, bending was used to give aerodynamic shape to the blade. Welding was used to connect the rotor blades to hub and all other components like tower and support frame.

Fig 13: Final Experimental Setup

Calculations

1. Length of the Rotor Blade

Length of the blade can be calculated by the power formula of wind turbine

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

Where,
P = Power in the wind
A = area with radius which is length of blade
v = velocity of wind
ρ = density of air
C_p = power coefficient

The expected power output is 50 W.

$$C_p = 0.45$$

$$\text{Wind speed} = 5 \text{ m/s}$$

Hence,

$$50 = \frac{1}{2} \times 1.2 \times 125 \times 0.45 \times 3.14 \times r^2$$

$$r = 0.7\text{m}$$

2. Number of Rotation

$$\text{RPM} = \frac{(\text{TSR} \times 60 \times \text{v})}{(\pi \times d)}$$

Where,

TSR = tip speed ratio = 5 for 3 blade turbine

v = velocity of wind

d = diameter of turbine (2 × blade length)

$$RPM = \frac{(5 \times 60 \times 5)}{(3.14 \times 1.4)}$$

RPM = 340 (aprrox.)

3. Gear Ratio

$$\text{Gear ratio} = \frac{\text{Generator RPM}}{\text{Rotor RPM}}$$

Generator RPM = 3000

Rotor RPM = 340

Gear ratio = 3000/340

Gear ratio = 8.82

10. TRIALS AND READINGS

RPM and voltage calculated are shown in the table for GI sheet:

Table 3: Readings of RPM and voltage during trials for GI Sheet

Wind Speed(m/s)	RPM	AC Voltage(V)	DC Voltage(V)	Current(A)	Power
2	9	36	25.71	0.5	12.85
3	18	67	47.8	0.5	23.9
4	36	127	90.71	0.5	45.355
5	54	142	101.42	0.5	50.71

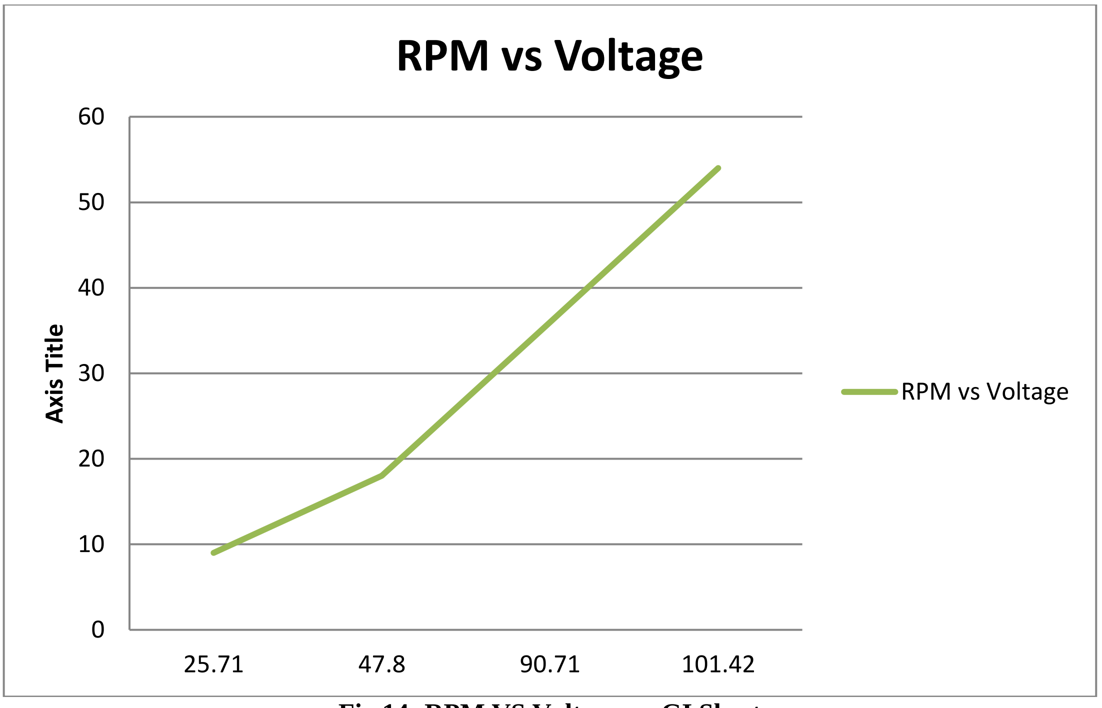


Fig 14: RPM VS Voltage on GI Sheet

RPM and voltage calculated are shown in the table forAluminium:

Table 4: Readings of RPM and voltage during trials for Aluminium

Wind Speed(m/s)	RPM	AC Voltage(V)	DC Voltage(V)	Current(A)	Power
2	12	41	29.2	0.5	14.6
3	24	72	51.42	0.5	25.71
4	45	130	92.8	0.5	46.4
5	63	148	105.71	0.5	52.855

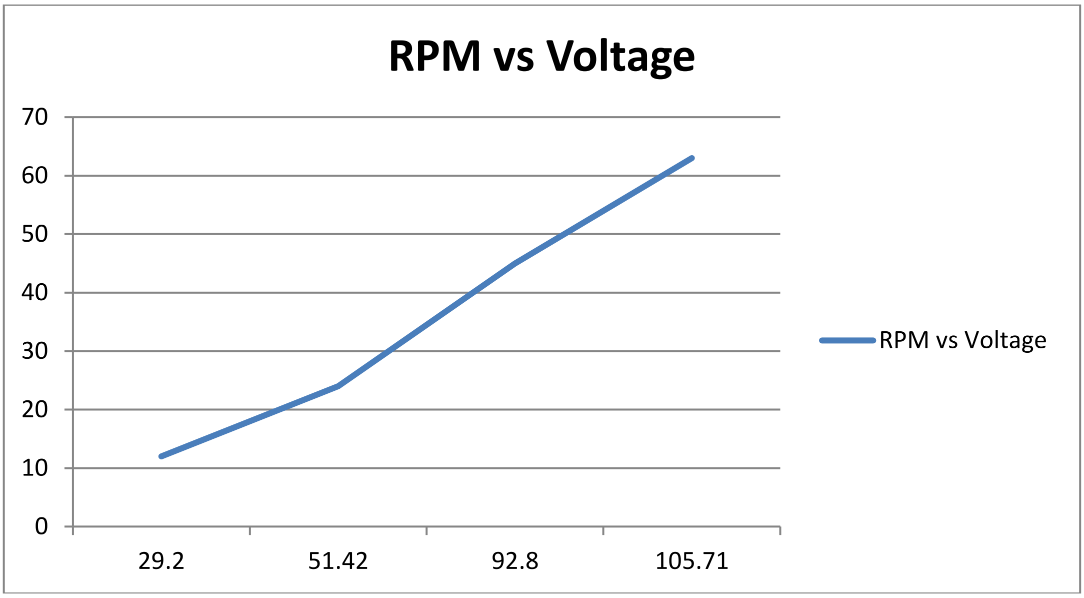


Fig 15: RPM VS Voltage on Aluminium

11. COST ESTIMATION

Table 5: Cost Estimation

Component	Material	Cost of one piece	Size	Quantity	Cost
Blades	GI Sheet	400	1m*1m*0.004m	3	1200
Blades	Aluminium		1m*1m*0.004m	3	800
Blades	PVC		1m*1m*0.006m	3	700
Bolt	MS	10	M4 8mm	3	30
Bearing	MS	80	–	2	160
Bolt	MS	50	M8 20mm	1	50
Synchronous Motor	–	1770	–	1	1770
Tower	–	600	–	1	600
Frame	–	350	–	1	350
Miscellaneous	–	340	–	–	340

Machining	1500

Total Cost for

GI Sheet Blades- 6000

Aluminium Blades- 5600

PVC Blades- 5500

12. CONCLUSION

Based on the experimental and analytical study a wind turbine can be fabricated with minimum cost to produce a power of approximately 50W. Also it was observed that with increase in wind speed, number of rotations was increase and voltage was also increased. Therefore, RPM is directly proportional to voltage. The maximum power output estimated was 52.85 W and minimum was 10.28 W. Through our market survey it was observed that micro wind turbine with rated power costs 12-15000 INR. But with change in materials of some components like blades of rotor and using synchronous motor can be used to minimize the cost of the turbine. In this research rotor blades were made of aluminium sheets due to its light weight. Also, structural and computational analysis proves that the deformation and stresses generated on aluminium sheet is less. Synchronous motor was used as a generator. Reverse principle of motor is used; by rotating the shaft of the motor electricity was produced. Further a bridge rectifier was used to regulate the voltage and current. This immensely reduced the costing of the turbine. Also numerical method assisted to calculate the length of blade and power output.

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