FABRICATION AND PERFORMANCE ANALYSIS OF PORTABLE VERTICAL AXIS WIND TURBINE

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ABSTRACT

In the current time environment situation, global warming, pollution caused because of burning fossil fuel and rapid decrease in available amount of fossil fuel, demands for cleaner energy sources are become a viable technology for power generation. Huge researches lead to use of wind energy and wind turbine installations. This paper shows the small research approach of power generation using waste wind energy at ground level with the help of VAWT. The main objective of this attempt is to produce electricity by using the kinetic energy of air that flows at low ground label to generate power. This project involves a fabrication of proto-type for a small scale portable vertical axis wind turbine for charging cellular electronic gadgets.

Key words: vertical axis wind turbine, portable vertical axis wind turbine, waste wind energy, ground level, charging cellular electronic gadgets

1. Introduction To Wind Turbine

As time passes it is getting more and more difficult to use fossil fuel to use it as a source of energy and it increases the pollution of air have compelled many countries to find and use the alternative energy sources, to meet their requirements. Till today our extensive source of primary energy has been fossil fuel for domestic, industrial and for power generation. But it comes with a serious threat of environment pollution and degrading mother earth. There are various types of energy. For example Potential energy in the water stored in a dam, the energy in a coiled spring, and energy stored in molecules (gasoline). Similarly kinetic energy is energy available in the motion of particles such as wind energy. The energy may be categorized as: mechanical, electrical, thermal, chemical, magnetic, nuclear, biological, tidal, geothermal, and so on. Renewable energy is a sustainable future energy resource. The future can be secured with clean energy sources if we prepare for it now.

Wind energy is converting wind kinetic energy into mechanical energy, which then can be converted to electrical energy that can be coupled with practical with the help of wind turbines.

Vertical Axis Wind Turbine:

For wind energy generation the wind turbine is the most essential part. Depending on their axis of rotation the turbines can be a horizontal axis wind turbine (HAWT) or a vertical axis wind turbine (VAWT). There has been various occasion we must have encountered HAWT.

But there is a bigger issue with HAWT is its size. It needs higher speed of wind to rotate the huge blades of it, which again space consuming. This type of wind turbine needs a continuous flow of high speed wind to rotate the blades. Also this type of wind turbine needs a large area of flat lands where we can mount.

Because of following advantages of VAWT, we can bring in to use for small power generation.

- The vibration and noise is lesser than horizontal-axis wind turbines
- It can generate electricity irrespective of the wind direction.
- It can produces electrical energy at very low wind speeds unlike HAWT.
- Blade speed is less as the blades are positioned closer to the axis of rotation.
- Can be installed in urban, residential and commercial areas.
- Looks beautiful and pleasing to eye unlike some larger horizontal wind turbines.
- Height of Vertical-axis towers are much less than horizontal-axis wind turbines.

Objective of project:

Being in the coastal area in India, this area faces cyclone every year, as well as in other locations also faces natural disasters time to time, in that case the HAWT get damaged greatly. Also to reduce the space consumption we are fabricating a portable type VAWT prototype which can be disassembled before the disaster.

Also in highway, or in beach area the KE of wind energy get wasted, in those areas we can't mount the HAWT, it will also be suitable for those areas to generate the power to meet the requirement of power for highway.

2. Design and printing

The design is adapted and modified according to the project objective. The first step is to produce a digital model. Frequently used process of producing digital model is computer-aided design (CAD). STL file is a similar file to stereo-lithography CAD software i.e. developed by 3D systems. Now, a CAD model is converted into an STL file. The STL file then transformed to G-Codes that control the 3D printer automation and check the essential parameters like layers & height.

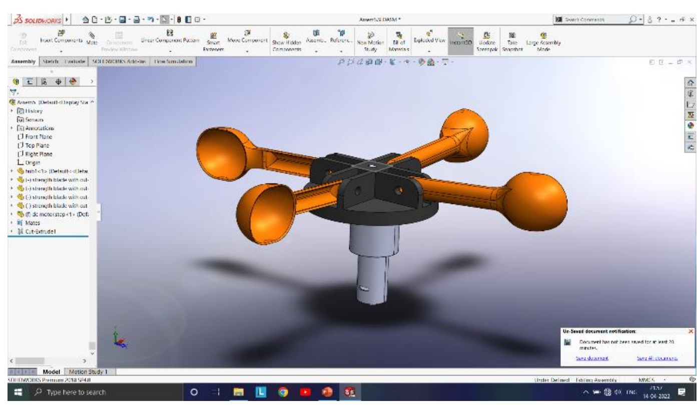

Fig. 1. 3D Model of Wind Turbine

MAJOR COMPONENTS OF VAWT

- Turbine blade.
- HUB.
- Alternator or 12Volt DC motor.
- Battery
- XL6009 DC- DC Adjustable Step up Boost Power Converter Module.
- Diode

3D printed parts

In additive manufacturing (AM) process a 3D objects is built by adding layers one upon other of specified material using a Computer. Unlike other conventional machining processes, 3D printing or AM can build 3D object using CAD model file, generally by continuous addition of material layer by layer. The 3D printed Model and its assembled structure is shown in following Figure.

ABS Material

ABS, shot for Acylonitrile Butadiene Styrene, is an oil-based plastic-type. ABS finds many applications in the manufacture of numerous components because it is easy-to-use and has high resistance to high temperatures. ABS might be perfect end-use components, also for functional parts such as those created in 3D printers of 3d printing service. It is a thermoplastic resin and can frequently meet the property requirements for a reasonable price, lieing between standard resins like PVC, polyethylene, polystyrene and such more and engineering resins like acrylic, nylon specially(taulman 645 nylon), acetal, and such more.

3. Fabrication Process

The FDM technology works using a plastic filament or metal wire which is unwound from a coil and supplying material to an extrusion nozzle which can turn the flow on and off. The heated nozzle which melts the material and moves in both horizontal and vertical directions by a NC mechanism, directly controlled by CAM software. The object is produced by extruding melted material to form layers as the material hardens immediately after extrusion from the nozzle. This technology is widely used with following plastic filament materials like ABS (Acrylonitrile Butadiene Styrene) and PLA (Polylactic acid) but more materials are there with properties like wood filed, conductive, flexible etc. Scott Crump invented FDM in the late 80's.He started the company Stratasys in 1988 after patenting this technology. The software in this technology automatically generates support structures if required.

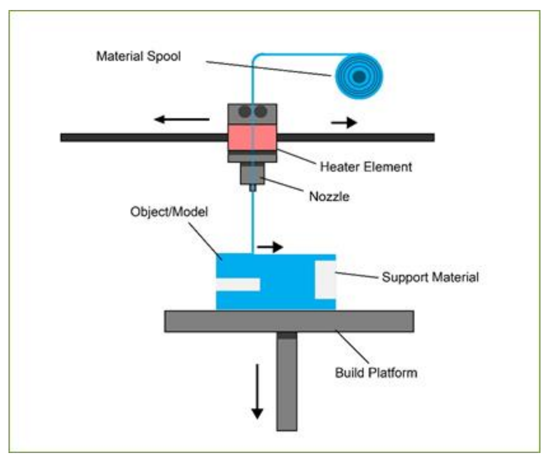

Fig. 2. 3D Printing Process

CREALITY ENDER 3

The Ender 3 Pro is a good printer for beginners because it's easy to set up and use and produces good-quality prints. It is helpful and affordable, which makes an excellent option for beginers in 3D printing. Also, there are many of online/offline tutorials to follow while using this printer.

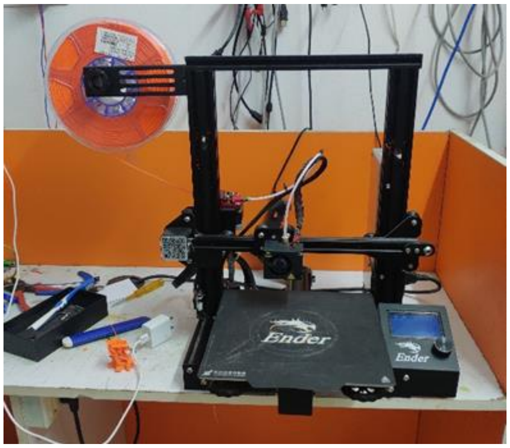

Fig.3 3D printer

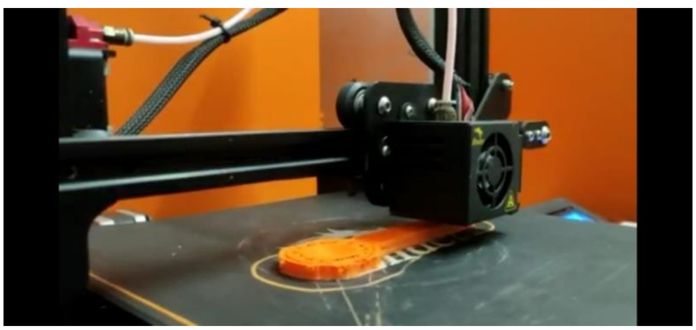

Fig. 4 Printing the 3D Object

Fig. 5. Final Prototype of Turbine

Fig. 6. Installed Prototype

4. Data Collection & Calculations:

Power in the wind:

Wind turbines generate power by converting the kinetic energy from the wind and transforming it into rotational energy. This is done with the help of a aerodynamic geometry, by creating a pressure difference between the air before the air entering the turbine and after it passed through the turbine. As the air flows gets disrupted by the rotating blades and slowed down them. Since air can be considered incompressible at low velocities, the air pressure is decreased to below atmospheric conditions just after passing through the turbine.

The air pressure remains in equilibrium when the air returns to the surrounding air pressure. As a result, the pressure increases at the cost of a drop in kinetic energy. Eventually, after the stream flows a substantial distance past the turbine it returns to the pressure and velocity of the surrounding air. The exact amount of power of the can be calculated from the wind speed, which need good understanding of fluid dynamics, and airfoil geometry. Yet, a plot between turbine power and various wind speeds can be estimated using simpler calculations based upon the theoretical formula for maximum energy in any given amount of air.

This value can be obtained from Equation.

$$\boldsymbol{Power = 1/2\ \rho A_{swept} v^3}$$

Where P equals Power, **ρ** equals the density of the air at the given atmospheric conditions, $\mathbf{A_{swept}}$ is the swept area of the turbine and **v** is the upstream velocity of the wind. Swept area is total cross sectional area that the blades pass through as they rotate. The swept area of a Vertical axis turbine, for example, is the area of the circle that connects the four blades together. Since the density of the air is both difficult to change and relatively constant for a given area, the main factor that influences power generation is wind speed. Doubling the turbine's swept area will only double the turbine's power output. However, doubling the wind speed will provide a significant increase in the turbine's power output. For example, if a turbine generates 1.916W at a wind speed 5.7 m/s.

Coefficient of Power

1. Like all systems, actual turbines do not operate under ideal conditions. The alive of drag, friction and other factors restricts turbine's power output. The coefficient of power (C_p) is the ratio of total wind power to turbine power.
2. Cp can be calculated using Equation

Cp = Actual Electric Power / Total Fluid Power

3. The maximum theoretical value for the coefficient of power is 0.092 as determined by the Betz limit.

Tip Speed Ratio:

Rotational velocity of the turbine shaft is essential as it dictate how much mechanical power the turbine produce. Speed Ratio (TSR or λ) is the ratio of blade tip speed to the wind speed, and thus it recount the wind velocity to the angular velocity of the rotor.

$$\lambda = R\omega v$$

In above equation, λ is the TSR, R corresponds to the radius of the turbine, ω is the angular velocity of the turbine blades, and v is the velocity of the wind.

Higher TSRs represents more power, but lesser value for torque, whereas lower TSRs represents higher torque, low angular velocities.

From the above installation highest TSR calculated 0.538 at a wind speed of 5.7 m/s.

S.NO	WIND SPEED	VOLTAGE	RPM
1.	1.9	0.45v	20
2.	2.2	1.02v	45
3.	3.5	1.64v	61
4.	4.4	2.95v	90
5.	5.7	4.51v	161

Table No. 1: Obtained Values

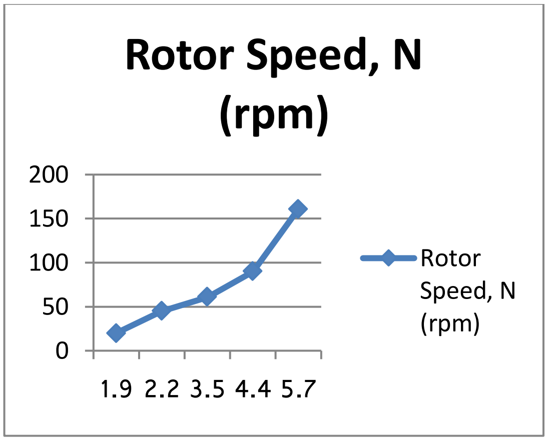

Fig.7. Graph between Wind Speed vs. Rotor Speed

V (m/s)	N (rpm)	Computed parameters		
		P_a (watts)	TSR	C_p
1.9	20	6.8	0.16	0.08
2.2	45	10.59	0.35	0.16
3.5	61	42.64	0.48	0.16
4.4	90	84.73	0.71	0.16
5.7	161	184.22	1.16	0.28

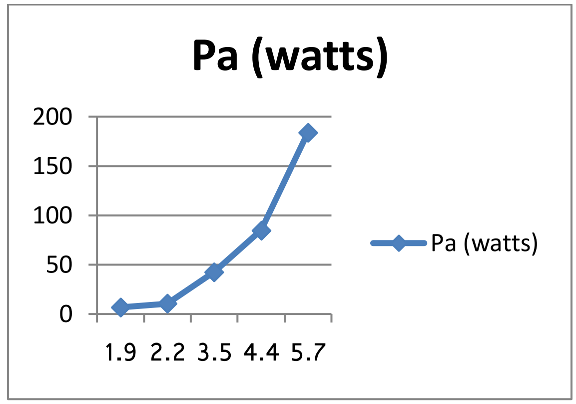

Fig. 8. Graph Between Rotor Speed vs P_a

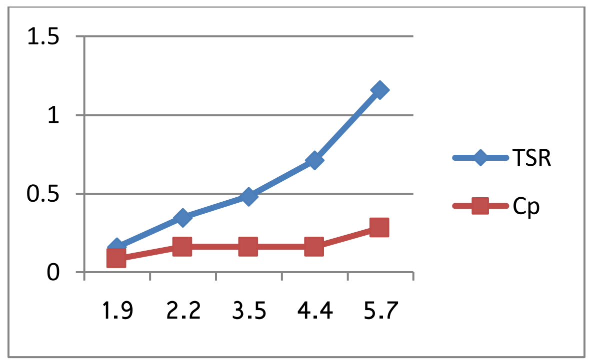

Fig.8. Graph between Rotor Speed vs. TSR, C_p

Table No. 2 Calculated From the Obtained Values Given:

Wind Speed, V (m/s)

Rotor Speed, N (rpm)

Power in the wind, P_a (watts)

Mechanical power, Pm (watts)

Tip Speed Ratio, TSR

Power coefficient, C_p

5. Conclusion And Recommendation

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 Solid Works soft ware and fabricated the prototype using 3D Printing process. Here we tried to develop a model which can produce the output even at low wind speed. Parts were fabricated with ABS materials. 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, minimum beach wind speed is of 1.9 m/s, which is much lower, and generated a power of 6.8 watts, which is sufficient to light Diode LED. So further research can give a more sustainable process of using this type of wind turbine in practical basis to meet the low power requirement of lightening arrangements outdoor such as high way.

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