e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:04/Issue:04/April-2022 Impact Factor- 6.752 www.irjmets.com

LOW WIND SPEED TURBINE WITH A NEW DESIGN PROCESS AND PERFORMANCE ANALYSIS

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ABSTRACT

The development of a novel technology is underway in order to produce a turbine can run effectively. This research study covers in detail a low-wind zone where the blades are intended to provide an efficient solution for a wind-related problem. Finalized designs various blade locations, using various blade forces and angles. As long as you maintain the necessary rotational speed, you will be able to visually see the distribution of velocity the blade. the blade's aerodynamic performance is examined, it is ensured that it meets design specifications and performs efficiently in a variety of wind speeds. As an alternative to using big diameter blades being used. While the theoretical maximum power output speed is 3.4 m/s, the real maximum speed is only 4.4 m/s, according to the data collected so far.

Keywords: Design For Aerodynamics, Performance Analysis, Blade, Turbine With Low Wind Speed.

I. INTRODUCTION

Wind energy is a kind of renewable energy that is incredibly efficient and is readily accessible in large quantities. Since before the Industrial Revolution, wind energy has been utilised to thresh crops and pump water, among other things. Large-scale wind turbines that generate electricity have become prevalent as a result of the slow and steady development of this technology through time. Wind turbines are obnoxious, make a lot of noise, and take up a lot of room. In remote locations with few population and a strong wind flow, wind turbines should be installed to generate electricity. In order to create electricity, coal and other fossil fuels are being used for the first time. These non-renewable clauses are expected to expire in the near future. The combustion of fossil fuels results in the emission of around 21.3 billion tonnes of CO2 every year. Because nature is unable to absorb all of the CO2, greenhouse gases are released into the atmosphere. Nature's forces are always generating and replenishing renewable energy resources. Wind, tidal, solar, geothermal, and hydroelectric energy are examples of renewable energy sources. This research project is focused on wind energy, which is an important source of renewable energy. Micro wind turbines have the potential to lower high energy costs while also acting as a buffer against rising power demand. This would minimise our reliance on fossil fuels while also assisting in the reduction of greenhouse gas emissions. Depending on local wind resources and utility tariffs, a modest wind energy system may reduce power expenses by 50 percent to 60 percent, according to the EPA. A freestanding system saves the customer money by eliminating the need to extend. However, it may also be connected to the power grid, allowing the customer to sell excess power or purchase more when needed via the use of a reverse-metering system. The initial capital expenditure pays for itself throughout the course of the wind farm's operational lifetime. Traditional windmills will be inappropriate for usage on a substantial percentage of the Indian land due to the low wind speeds present on the area. Because of the large transmission losses in India, it may be necessary to locate the turbine in close proximity to the point of consumption.

II. LITERATURE SURVEY

Wright and Wood (2004) investigated the behaviour of the turbine (HAWT). During their research, they observed that while the wind speed is low, the blades create a significant amount of torque. In order to predict a significant increase in torque as a result of unsteadiness, low frequency must be taken into consideration. there was a significant amount of 'idle time,' during which the spinning blades were only slowly accelerated. According to Habali and Saleh, wind turbines are capable of operating even under low wind speeds (2000). This was made feasible by the optimization of the rotor blades, which is the most significant aspect of a wind turbine and the most expensive to manufacture. Hirahara et al. (2005) the performance of the turbine to that of similar commercial turbines and find it to be particularly impressive at low turbine rotation speeds. A 1.5 kW tiny wind turbine system with a 12 m hub height and a 3 m diameter rotor was discovered in Turkey by Ozgener (2006), who published his results in 2006. The findings of the performance analysis were quantified in the article. Arifujjaman and colleagues developed a model of a micro-wind turbine that included a furling mechanism (2008). As seen in the video, the model replicates the process of regulating the speed of a wind turbine generator. A tiny wind turbine's tip speed ratio, as well as hill climbing control systems, are being examined for their potential to enhance power production. It is small-scale wind turbines that generate electricity in the built environment that are referred to as micro generating technology. A technique developed by Bahaj and colleagues (2007) was used to determine the feasibility and economic viability of small wind turbines for residential usage. Ditkovich and colleagues developed a performance measure for turbines operating at constant and variable speeds (2014). Using the Weibull wind probability distribution function and a power curve provided by the manufacturer, this approach calculates the wind speed. A recent focus has been on a tiny wind turbine (Xu et al., 2013) that has the potential to power low-power electronics such as cell phones. It has been developed a physical model for predicting the performance of micro HAWTs. Compact wind turbines used in coastal and island regions need durable construction as well as protective measures in order to operate reliably over long periods. Dong and colleagues developed and tested a miniature wind turbine prototype that is ideally suited for use on islands (2013). Using statistical modelling. Johansen and Sorensen (2006). It is difficult to simulate flow through a HAWT with untwisted blades because of the spinning, turbulence, and stall effects caused by the turbine's blades. A revolving wind turbine may be depicted using either a static or dynamic grid, depending on the situation being considered.

In this study, we discuss a novel design approach for blades that has just been developed. The last point to mention is that locating the power-generating source closer to the power-consuming locations minimises transmission losses. According to the statistics, the blade performs effectively in areas with little wind.

III. MODELING AND ANALYSIS

3.1 Aerodynamic design

The blade's aerodynamic design consists of three parts: rotor, airfoil, and blade. When planning and manufacturing a wind turbine, the rotor's dynamic, strength, and fatigue properties must be considered. The rotor tip moves at a much faster pace than the blade root, hence it is given considerable attention in blade design.

3.2 The wind speed is used to pick the turbines.

It is possible to calculate three design speed parameters, namely, the cut-in wind speed Vcutin; the rated wind speed Vrated; and the cut-out wind speed Vcutout; by applying equations (1), (2), and (3). (3).

_ vcutin ��0.7u (1)

_ _ 1.5u ��vrated ��2.0u (2)

_ _ 1.5u ��vrated ��2.0u (3)

3.3 Design of the rotor

A rotor may have any number of blades, airfoils, chords, twist distributions, and materials. Often, conflicting interests must be prioritized in order for these solutions to be successful. In this case, HAWT is used. The rotor size may be estimated using equation, The wind turbine's diameter in millimeters The blade diameter of a six-bladed rotor is projected to be 1,902 mm.

Table 1: indicates the non-dimensional length of the linear chord and profile thickness

X ��x / l	y ��y / ymax	X ��x / l	y ��y / ymax
0	0	0.2	0.85
0.001	0.15	0.25	0.851
0.003	0.096	0.5	0.856
0.01	0.156	0.38	0.98
0.0098	0.198	0.45	0.856

0.1	0.3	0.55	0.9
0.102	0.395	0.657	0.6892
0.04	0.487	0.75	0.621

3.4 Selecting an airfoil

When compared to other airfoils, this one produces the greatest amount of lift while simultaneously lowering drag. It was found that this airfoil functioned effectively in small domestic wind generators. The considerable lift force of the airfoil makes it an excellent choice for low wind speed turbines. It is feasible to get a greater L/D ratio when using non-symmetrical profiles.

3.5 A wind tunnel test was used to determine

The wind tunnel blade angles were investigated. Following the selection of the airfoil based on the design criteria, numerous blade angles were tested in a variety of wind speeds to determine their performance. An illustration of this would be a pressure graph and a slenderness curve depicting the relationship between lift and drag forces, respectively.

3.6 Blade design

In the development of future wind turbine technology, the design and engineering of the blades themselves is a difficult and critical part. An attempt was made to maximise the amount of energy harvested from the wind by creating blades that were robust, silent, and cost efficient while also absorbing as much energy as possible from the wind.

$$D_a = D_h + 0.02D_2 \quad [4]$$

$$D_e = D_2 - 0.02D_2 \quad [5]$$

$$D_c = (D_a + D_e)/2 \quad [6]$$

$$D_b = (D_c + D_a)/2 \quad [7]$$

$$D_d = (D_e + D_c)/2 \quad [8]$$

Science-based experimentation, modelling, and testing were all components of the engineering technique in issue. When evaluating the lift capability of a blade, a number of factors were taken into consideration. These factors included the shape of the blade, the speed at which air moved around it, the wind density in the surrounding area, and the blade's angle with respect to the apparent wind speed. Consequently, the blade is divided into five segments, with Dh representing the diameter of the centre hub.

This ensures that the design will be able to use all available wind energy. The design optimises the extraction of wind energy. When designing a rotor, the lift-to-drag ratio is the most critical factor to take into consideration. During the rotation of a blade, the forces and speeds experienced by each segment of the blade fluctuate. The distance between them and the root causes their velocity to rise. In other words, as the blade nears the rotor's tip, the relative importance of each component grows in importance. As the wind travels closer to the root, the angle of attack rises, resulting in increased lift and torque, even at moderate wind speeds, even when the wind speed is mild. Additionally, Rotor blades are continually pressurised as a result of the twisting moments that occur. It is the moments between the centre of pressure and mass centroid that cause the twisting to occur across the chord line that causes it. For this reason, the blade is constructed. The mass centroid will always be ahead of the pressure centre, regardless of the angle of the blade (within its operating range).

In a rotor with long blades and high rotor speed, the tip speed of the blades rises, creating pressure waves that cause rotor drag, which in turn causes turbulence, which limits power production. Having a quick tip speed is also the most essential design characteristic that has an impact on the amount of noise that is produced. As a result, we can expect to see more blade designs with low rotational speed and strong L/D performance in the future. The need of blade circulation was stressed because of the frequent bending that might cause fractures and eventually destroy the blade. Metal fatigue is a significant problem in a variety of industries, and metals are not suggested as rotor blade materials because of their low resistance to corrosion. Consequently, reinforced fibre polymer is employed in this application. It would be impossible to minimise the internal stresses in these blades unless appropriate composite materials were discovered. Because of their small weight, they are able to withstand the interior tension.

The blade is examined using computational fluid dynamics (CFD) (CFD). The investigation takes into account all of the conditions that must be met by the experimental setting in order for the blade to function successfully. The velocity distribution of blades, as well as the lift force and drag force of blades, are all investigated and researched. The data from the pressure drop analysis is used to formulate conclusions. The geometry of the blade is first cleaned up, including the removal of edges and the simplification of the blade.

After that, the blade is polished. The edges that are too close to the deleted items have been highlighted in red. Overlapping or damaged surfaces are bonded together to form a single smooth blade profile, which eliminates the possibility of problems in the future. Meshes must be created after the geometry has been cleaned. The wind turbine is enclosed in a cylindrical enclosure that is meant to accommodate the rotor with a particular amount of positive tolerance.

The MRF zone is included inside this perimeter. In the air domain, a larger cylindrical envelope is constructed in a manner that is concentric with the MRF zone. The air domain must be large enough to allow the wind to easily move through it without encountering turbulence or reflection from other objects. If the air domain is too small, the analysis will be unsuccessful. After that, the wind turbine is removed from the MRF zone and stored somewhere else. After then, the MRF zone meshes. Figure 6 shows the blades coming together. Meshes are created with the help of the Star-CCM. 'Trimmed cells' are used to construct the volume mesh. The term "input parameters" refers to any and all of the parameters required for the analysis.

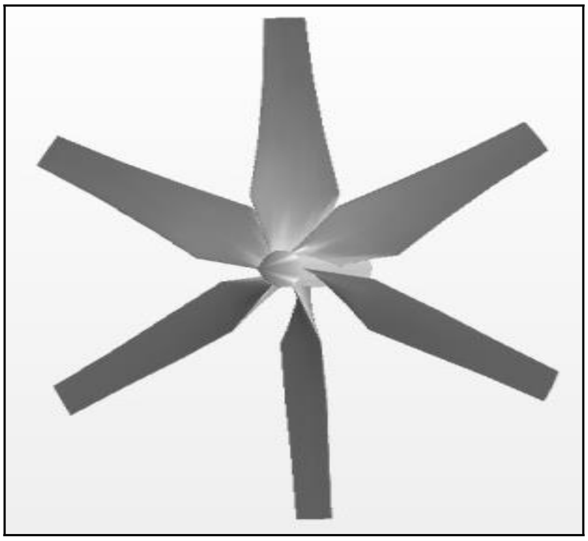

Figure 1: 3D blade model of the blade

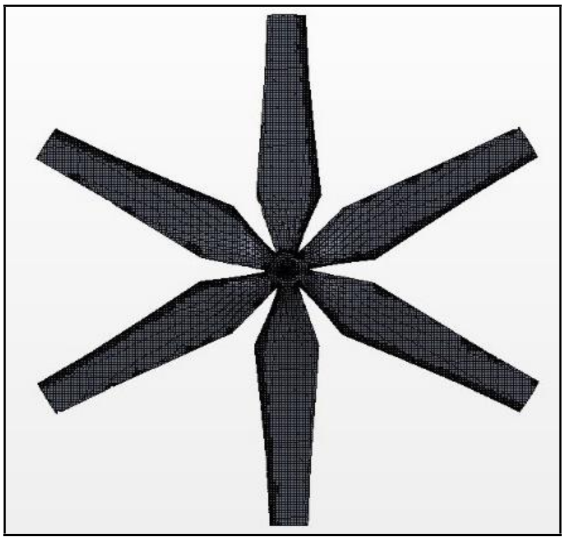

Figure 2: Trimmed cells type of mesh in the blades

3.7 Blade Making and Turbine Building

When it comes to milling blade patterning, wood with great dimensional stability is the best choice. As soon as The first blade is made using a wooden template as a template. The original blade is then used to create a fibreglass mould, which is ultimately recycled. The blade is then covered with layers of glass fibre, fibreglass, and resin to create the finished piece of equipment. A fibreglass mould is created in order to guarantee that the blades have flat surfaces, which prevents turbulence and resistance from emerging. To put it another way, composite materials have a far longer fatigue life than metallic materials.

The blades are reinforced with fibreglass to prevent them from breaking. The fibreglass layers are allowed to dry before being coated with a membrane and then sealed around the mold's circumference. Resin transfer moulds are used in this procedure. Injecting catalysed resin between the mould and the membrane while applying pressure and vacuum to fuse the two parts together results in more consistent, higher-quality products with a fibre content of 70% or more. Figure 3 shows the geometric model as well as the real blade that was constructed utilising the model.

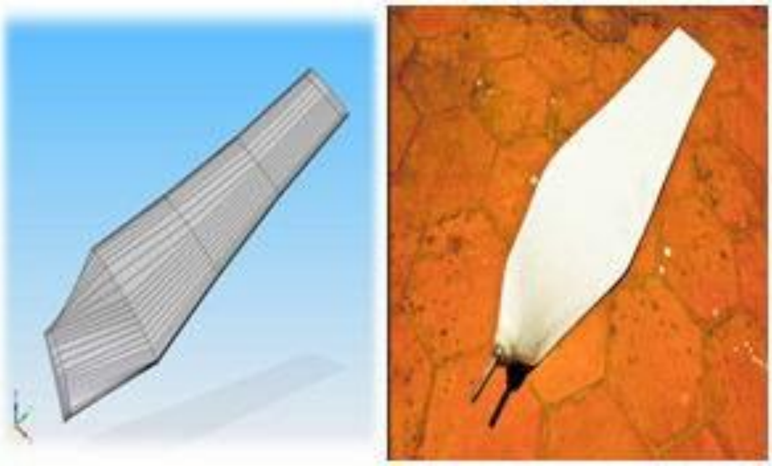

Figure 3: Aerodynamic design and prototype blade

All of the blades are joined to the generator's cylindrical hub, which is either bolted or screwed into place. It is possible to create a wind shadow when the wind bends away from the tower before reaching it. With the use of steel bolts, the tower's base is anchored to the concrete foundation. Additional wind stability is provided by the use of stay wires, which are attached to the tower's structure.

When the blades and generator are installed, During the course of a year, an engineering model was constructed and tested with varied wind speeds. Results that are awe-inspiring Because the field testing were conducted in "unrestricted air," they required a considerable time to complete. It was possible to attain the desired output at 32-36°C, 101.3 kPa pressure, and 1.149 kg/m3 density. As a result, when low wind speeds were reported, additional sources of wind energy were employed to evaluate the wind turbine's overall efficiency. The generator output power and generator output voltage are the measurements that are being researched. In order to validate the design method employed, or to generate the greatest power possible for the associated wind load, a monitoring system may examine.

IV. PERFORMANCE ANALYSIS

Schematic representation of the turbine with electrical circuit.

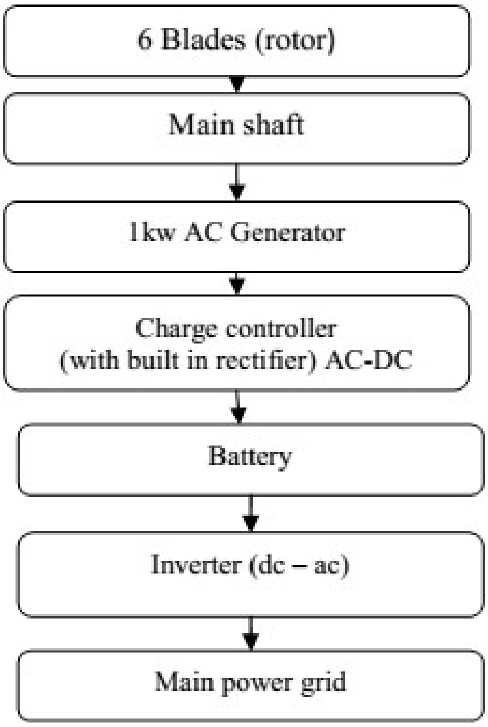

Figure 4: Schematic representation of the turbine.

V. RESULTS AND DISCUSSION

The study of computational fluid dynamics provides some intriguing findings. The average wind velocity striking the turbine blades when the turbine is operating at full capacity is seen in the illustration. It is as a consequence that the blades' speed is greatest at their tips and slowest in their hub. The operating at their maximum velocity ensures that the axes are in proper alignment. This investigation also revealed that the turbine spins in the anticlockwise direction. The pressure contour of the incoming air was examined, and it was discovered that the air exerts pressure. pressure on the blade surface ranges between 100 and 200 Pa, reveals that the darker zone corresponds to a high-pressure region that is revolving counterclockwise on the blade surface.

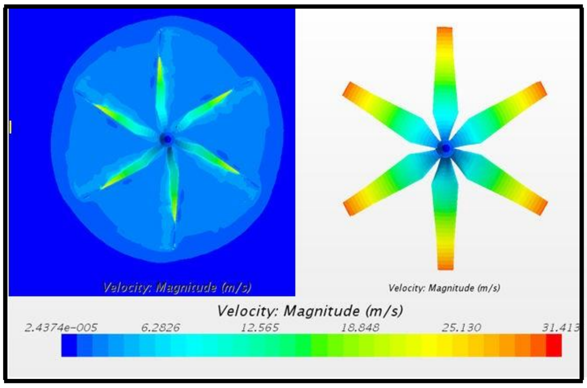

Figure 5: Distribution of contour of velocity blade

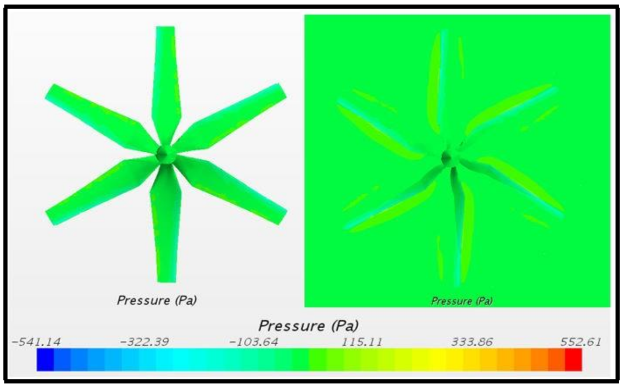

Figure 6: Distribution of contours of pressure over the over the blade

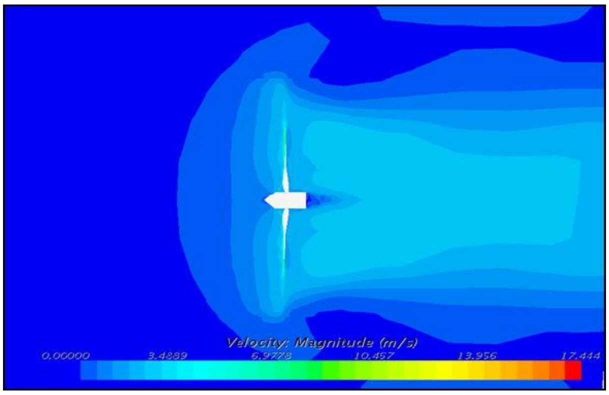

Figure 7: Velocity magnitude at unit

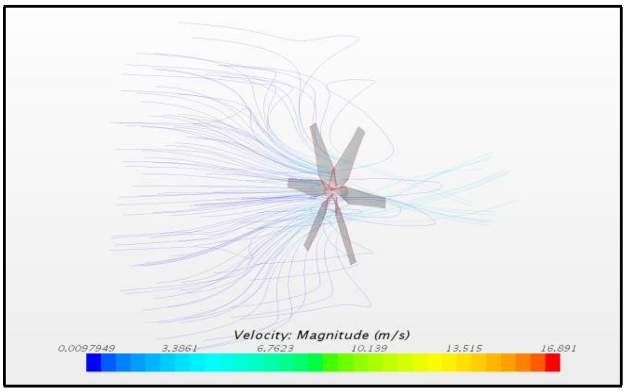

Figure 8: Velocity streamline of the rotating blade

Because the inner blade span contributes just a small proportion of total blade torque, these pressure graphs have minimal impact on the overall computing power output of the machine. Flow of wind through the turbine blades is shown in Figure 9 as being constant. A transient state analysis is characterised by the fact that the wind direction changes once per second. After flowing through the blades and forming a collective motion, the wind seems to rotate uniformly around the blades when analysed at a steady state depicts how streamlined air is forced to flow between turbine blades.

When it comes to velocity at rated power, the computational answer is quite close to the experimental data. Because the turbine is spinning, it sucks in and expels air from in front of the blades, resulting in a reduction in pressure near the turbine's centre of gravity. The wind seems to be focused around the middle of the turbine. Because of the high blade angle at the root, even a modest wind speed results in a significant initial torque.

The generator O/P vs wind velocity curve shown in Figure ensures that an appropriate design is selected for the low wind speed areas. The cut-off velocity of the wind turbine is 1.6 metres per second, while the maximum output power is 4.4 metres per second. The wind turbine produced a maximum of 1,008 W of electricity, surpassing the design parameters by a significant margin.

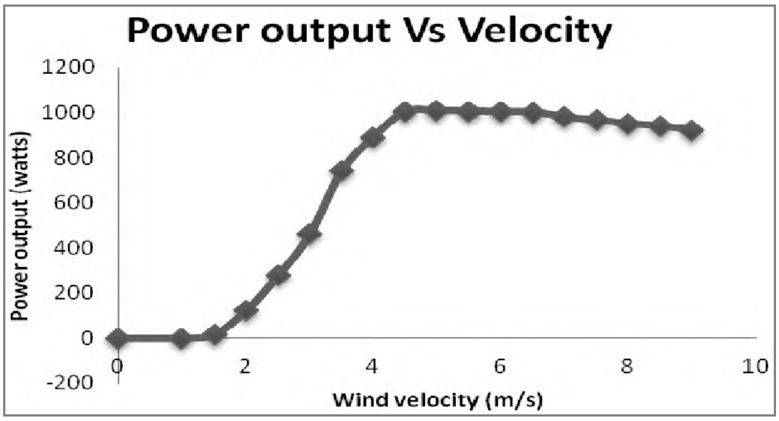

Figure 9: Power output vs wind velocity

VI. CONCLUSION

The power of 1 kW was established after extensive testing, which was then confirmed using CFD analysis. The results of the wind tunnel studies were critical in determining the blade angles since they provided information on the lift-to-drag coefficients at various places throughout the blade's whole length. Based on measurements of the blade design and performance done at 300 rpm, it was determined that the maximum power production was achieved at 3.4 m/s. 4.4 metres per second wind speeds provide the greatest rated power output of all of the wind turbines. The blades have been developed to be as efficient as possible.

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