

# Design and Analysis of Horizontal Axis Small Wind Turbine for Low Wind Velocity Using QBlade

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## Abstract

Renewable energy systems are of high importance considering the present day energy requirement. In Wind energy systems design and analysis of wind turbines for enhanced efficiency at low at wind speed is studied in this paper. Aero foil shape is the one of the key aspects which determines the efficiency of the turbine. In this paper airfoil G4510, NACA 0018 and NACA 4412 are considered for the study with a blade length of 0.762 m. General Public Licensed Software QBlade is used for the simulation which uses Blade Element Method (BEM). Comparison of performance parameters for different aero foil is presented and blade is designed using G4510 airfoil nomenclature. Using these blades, a three bladed rotor is assembled and structural analysis is performed to know the pressure distribution on different areas of the blade. Finally, a tower is attached to the rotor assembly and simulation is carried on the small wind turbine. Graphical relationship between power, tip speed ratio, velocity and coefficient of pressure is obtained for analysis.

**Keywords:** BEM, HAWT, QBlade, Rotor, Wind Energy

## 1.0 Introduction

For the environmental and economic sustainability, the world is targeting for renewable energy sources. To reduce the concerns to some extent related to global energy demand, global communities are trying to find alternate energy production and saving strategies; also implement these technology and strategies to different economic sectors. The energy production here will be relying on the renewable energy resources. In this context, wind energy development will play a very major role to meet the energy demand in future, which also reduces environmental pollution and maintain clean and sustainable environment. As it is known that, the primary energy sources which are fossil fuels and coal are expected to deplete at a higher rate due to exploited usage. The release of carbon dioxide due

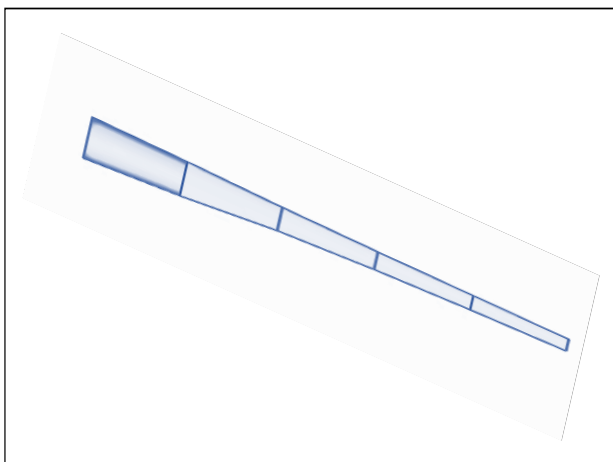
to the usage of these sources is causing serious threat to the environment and is contributing in a large amount to cause environmental pollution and also to cause climate changes in adverse manner. This can be one reason why clean and sustainable alternative energy sources are in need not only in India but in all the countries. Hence it is very important to replace the pollution causing energy sources by the energy produced using solar, wind, tidal energy etc. Among these energy sources, wind- power farms are used widely all over the world, wind energy has been considered as a very important source of energy. It is used for various purposes like windmills, pumping water and sailing boats. Through various approaches in the wind energy domain, there are many scientific studies to solve such problems<sup>1-4</sup> also the trend towards renewable resources and wind energy increased after the energy

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crisis<sup>5</sup>. With increasing problems related to environment, generation of clean energy becomes a significant aspect of energy consumption. In last 10 years, development of wind energy has been vast and is extended for industrial use by many major countries. Their success can be taken as encouragement by other countries to consider wind energy for generation of electricity<sup>6</sup>.

## 2.0 Horizontal Axis Wind Turbine (HAWT)

Horizontal Axis Wind Turbine (HAWT) is a wind turbine which has axis of rotation of rotor parallel to the ground and also to the wind direction. At the top of the tower, it has a shaft and an electric generator. Rotor blades are one of the important components of wind turbines. The structural design of horizontal axis wind turbine must satisfy some of the objectives like minimizing the weight and cost, resistance to fatigue loads, restricted tip deflections, and avoiding vibrations<sup>7</sup>. The blades should be light weighted, durable and corrosion-resistant material. In order to reduce weight, the materials used for manufacturing blades are fiberglass and reinforced plastic. For horizontal axis wind turbines, there are two types of blades which are normally mounted at two different conditions of wind. One type is lifting style, which is most efficient. These types of blades are mainly for capturing fast wind. Second type of blade is drag style; it is mainly used in windmills. Normally it is a flattened plate and is not suitable for high winds. In this paper, the blades for horizontal axis wind turbine have been



**Figure 1.** Designed blade for HAWT.

designed as shown in Figure 1 and simulated using QBlade software.

## 3.0 QBlade

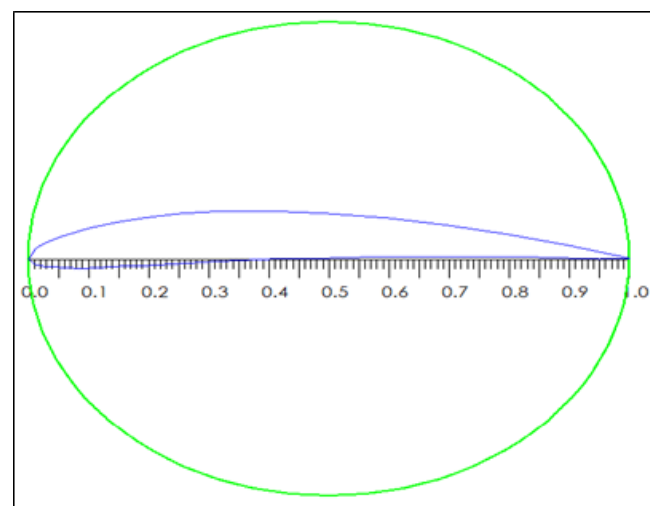
The software QBlade<sup>8</sup> is used to design the blade for a wind turbine and simulate for different conditions of wind. It facilitates very convenient platform to study the performance of the blade and generates graph for different aerodynamic parameters. This software there's no need of importing, converting and processing from any other external sources. Also this software is available freely under General Public License (GPL)<sup>9,10</sup>.

- Functions of QBlade software:
- Airfoil design and analysis.
- Lift and drag polar extrapolation.
- Blade design and optimization.
- Turbine definition and simulation.

Upon opening the software, we get the home screen which provides two design options of HAWT and VAWT. By opting HAWT option, we can get the tabs like rotor blade design, rotor Blade Element Momentum method (BEM) simulation, turbine BEM simulation, Multi-parameter BEM simulation etc.

### 3.1 Profile Input and Design

By clicking on to Aerofoil design tab and by adding predefined Aerofoil profiles can be investigated for required parameters. It is convenient to add two or more



**Figure 2.** Blade Profile Design.

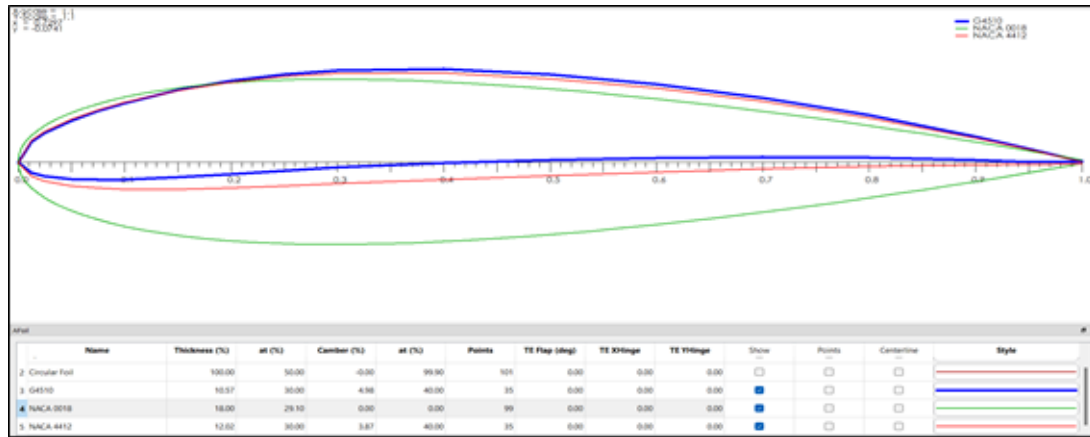


Figure 3. Multiple Airfoil Profile input.

profiles in a single window so that comparison becomes easier. In Figure 2, airfoil characteristics of G4510 can be seen in the profile which is indicated in blue color. The green curve indicates the circular foil profile which acts as reference.

The Figure 3 shows multiple airfoil characteristics in a single profile indicated in different contoured curves. The color blue indicates the airfoil G4510, red indicates NACA 0018 and green indicates NACA 4412. This helps in comparing all the entered airfoil's performances at the same time and in single profile. This also gives graphical result in the same graph.

### 3.2 HAWT Rotor Blade Design

This module gives blade profile design of wind turbine blades. For the turbine, we should have to enter some of

the parameters like values position, chord, profile shape and polar designs. It also allows customizing the display of rotor, views, foil names for better view while designing etc., as shown in Figure 4.

The designed blade is then assembled as a rotor by altering the positional value and shape of the turbine rotor. By maintaining the uniform curvature of the rotor, the body of the rotor is shaped as shown in Figure 6.

### 3.3 Structural Analysis of Rotor

By clicking on the QFEM tab, we get the stress analysis results for our airfoil. In this case the wind in-speed is taken to be 6 m/s. This simulation shows how much stress the airfoil is experiencing in its real life applications. As indicated in Figure 6, the root undergoes the maximum stress of the setup, whereas the tip

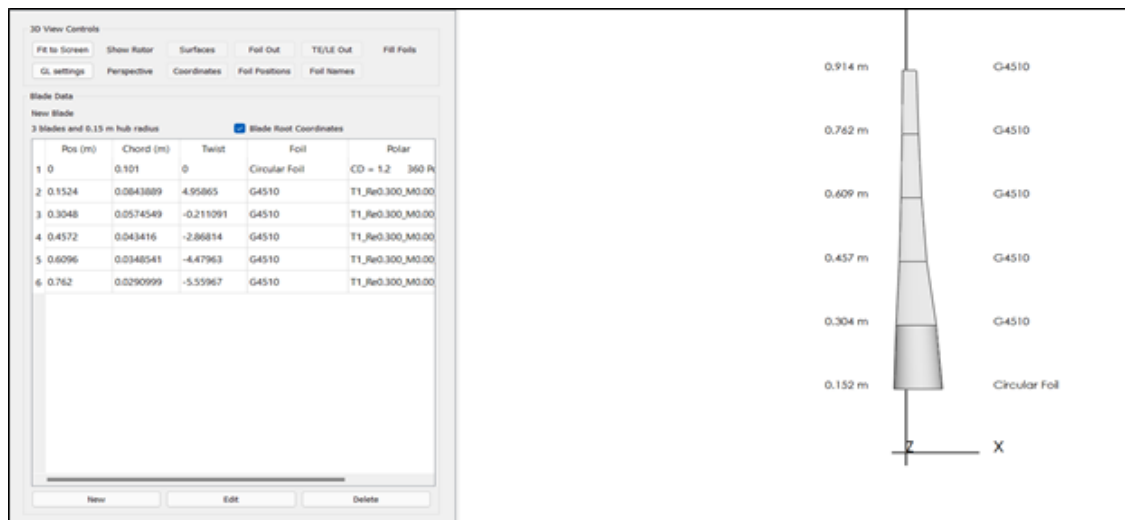
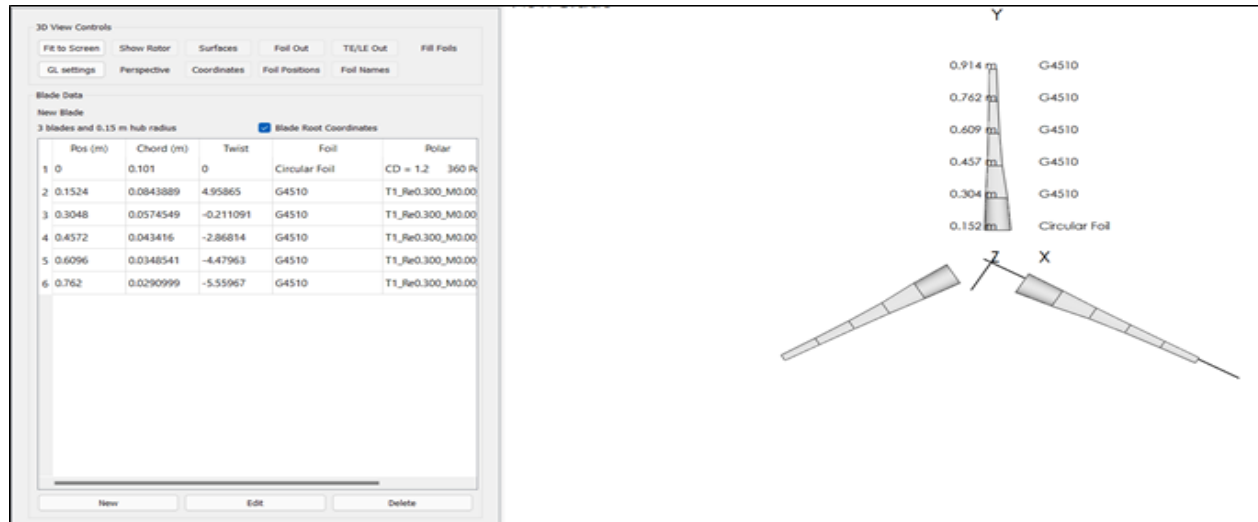
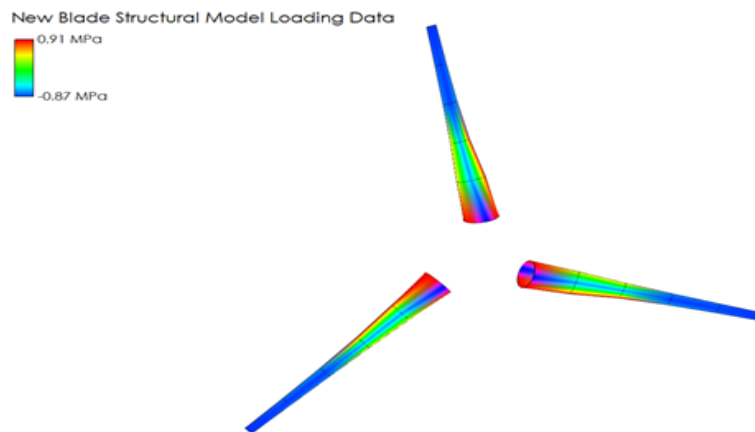


Figure 4. Customization of Rotor blade sections.



**Figure 5.** Resultant HAWT Rotor Blades.



**Figure 6.** Structural analysis of the rotor assembly.

experiences negative stress which indicates that the blades are bending in the direction of wind. The blades are designed keeping in consideration they may tend to bend inward or outward. Hence the fabrication material needs to be a highly elastic and needs to have great tolerance.

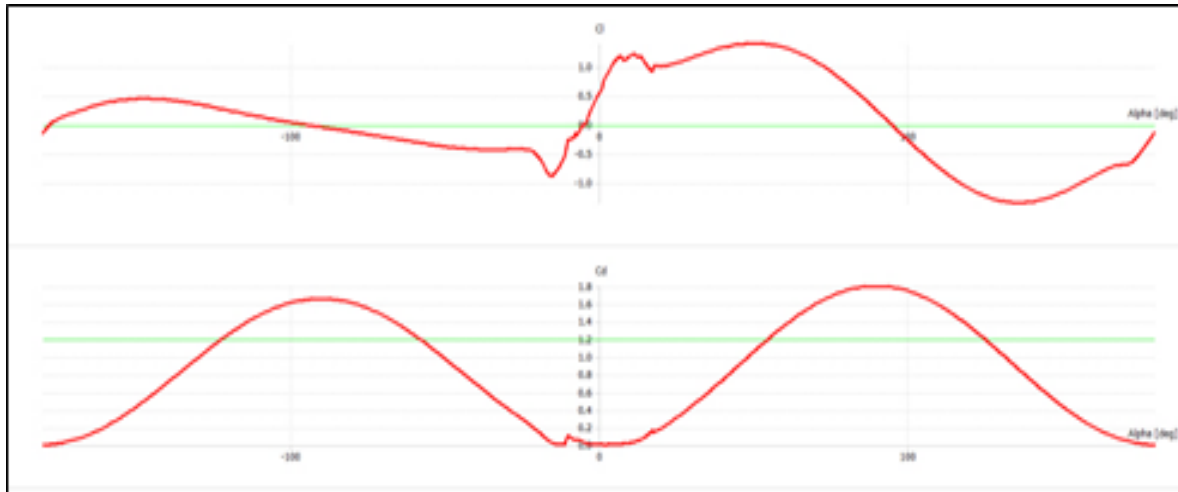
### 3.4 Polar Extrapolation to 360°

By clicking on polar extrapolation to 360° tab, we get the extrapolation results of our airfoil; in this case we have extracted the results with reference to a circular foil covering the airfoil from leading edge to trailing edge. The circular foil is indicated in green color in Figure 7.

This extrapolation shows very simple approximation of the “real” airfoil behavior.

### 3.5 X Foil Analysis

By clicking on the X Foil Direct analysis tab, we get the pressure distribution results on the airfoil; the pressure distribution is shown in the bottom half of Figure 8. This figure indicates the pressure distributed over the airfoil surface. The stall angle predicted by the XFOIL is approximately 18°, which is slightly higher than the experimental value i.e., 16°. We can browse through different Angle of Attacks through a tab labeled as Operational points. By changing the angle of Attack, we



**Figure 7.** Creating X foil polar.

can see the variation in pressure distribution on the airfoil surface which is an important aspect in efficient working of the model.

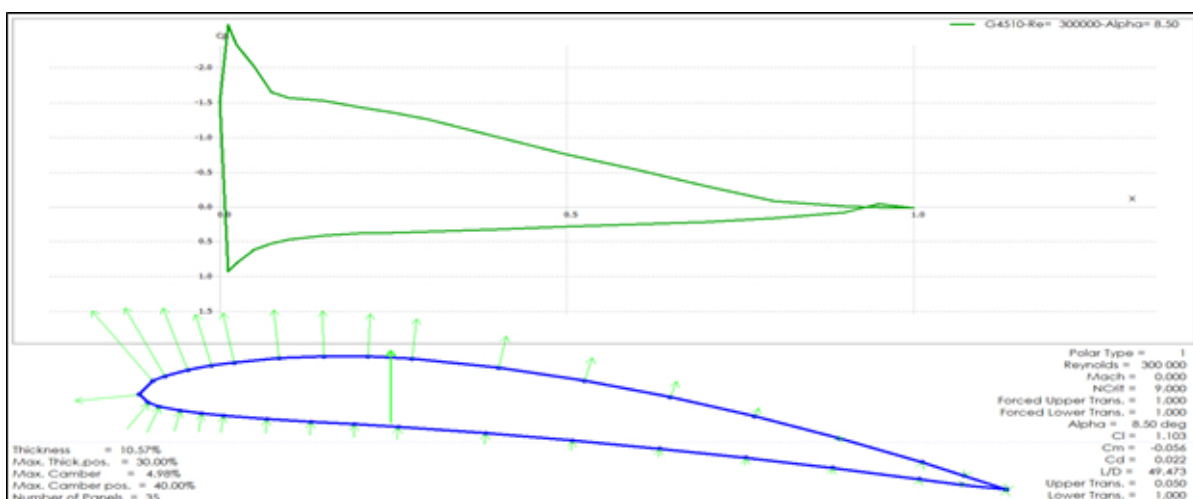
### 3.6 HAWT BEM Simulation

Here the analysis is based on classical BEM (Blade Element Momentum) method. By clicking on Rotor BEM solution tab, we get the simulations as in Figure 9. We can browse through different values of Tip Speed ratios, we can set the start and end tip speed ratio for the rotor, specify the delta tip speed value and obtain results for the desired

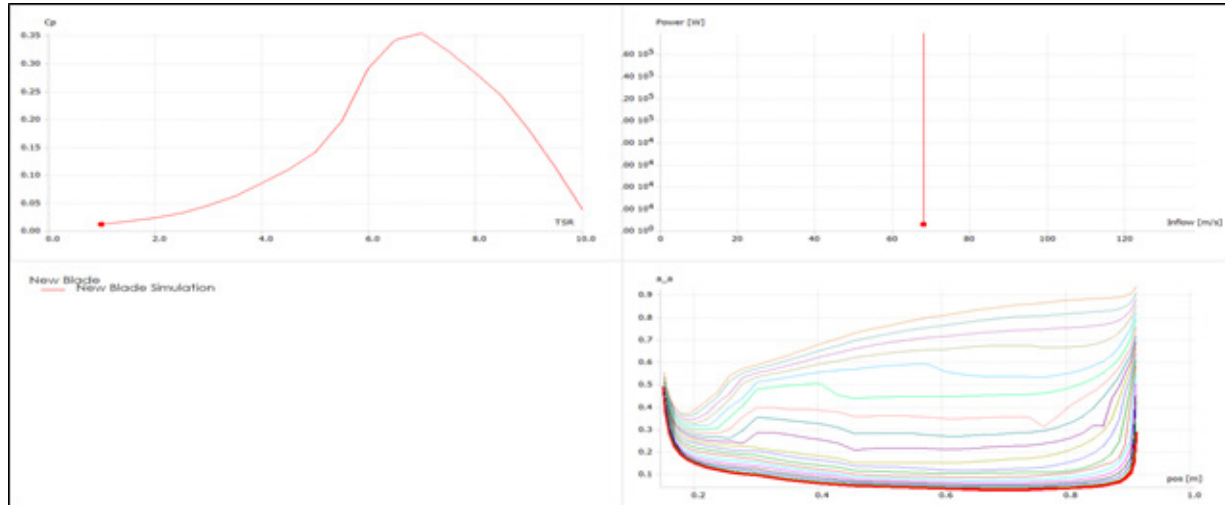
values or inputs. With change in the tip speed ratio the nature of graph changes drastically, same is the case with the characteristics of the rotor.

### 3.7 HAWT Multi-Parameter BEM Simulation

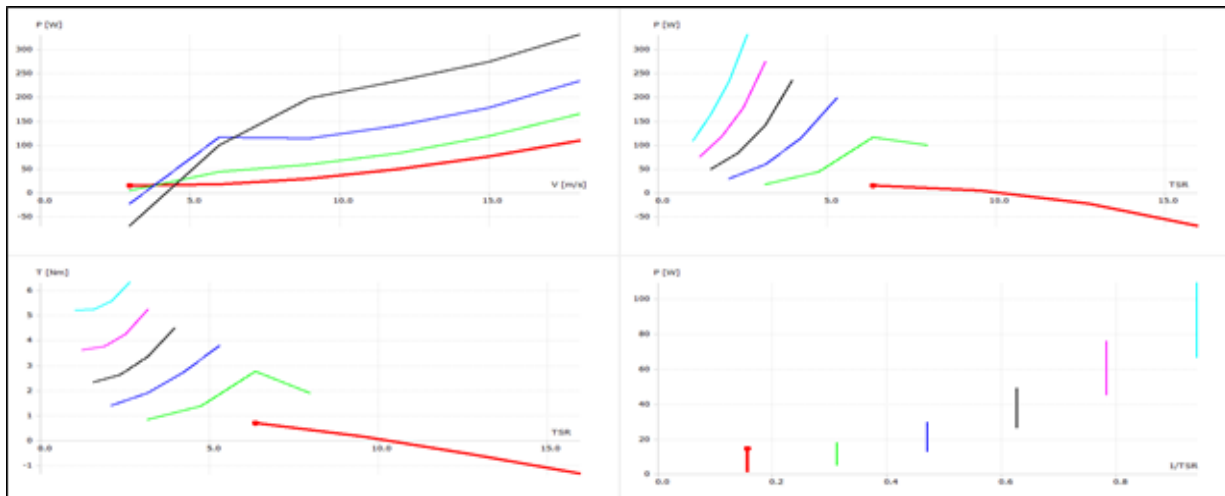
By clicking the Multi-parameter BEM Simulation tab, we can obtain the graphs as depicted in Figure 10. The results obtained define the power output capabilities of the designed HAWT. We can scroll through different values of inflow Wind speed, Rotational Speed and Pitch



**Figure 8.** Pressure Distribution along Aerofoil.



**Figure 9.** HAWT BEM Simulation results.



**Figure 10.** Multi parameter BEM solution.

**Table 1.** Rotational speed and power output information

Airfoil	G4510
No of Blades	3
Blade length	0.762 m
Velocity	8 m/s
Power	146 Watts
Rotational Speed	253 rpm

of the blade. We need to first specify the range of these above-mentioned parameters in order to obtain results (Table 1).

## 4.0 Conclusion

The analysis procedure in QBlade underwent multiple iterations to ascertain the optimized values for performance parameters in the design and analysis of Horizontal Axis Wind Turbines. Following the successful completion of the QBlade trials, graphically presented the optimal values for power, coefficient of performance and

Annual Energy Production. QBlade proves to be highly effective compared to other simulation software due to its inclusion of various blade profiles, such as NACA profile 4 and 5 digits. The simulation results were instrumental in evaluating the overall performance and pressure distribution on the designed blades.

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