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Parametric Analysis of 20KW Horizontal Axis Wind Turbine

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ABSTRACT

Wind energy is harvested by using kinetic energy of air in motion to generate mechanical powerful. Energy has become a more power, sustainable, renewable source of power. Pakistan is uniquely positioned in terms of its energy potential. More than 6% of Pakistan's electricity is generated by wind power. The focus of the research is on meeting Pakistan's energy needs in a small range. The approach produces about 20 kW of power, which can provide electricity to about 30 homes per year. Karachi, Sindh in Pakistan, is the area chosen for this study. The design parameters like tip speed ratio (TSR), wind speed, and efficiency factor are verified by the Warlock wind turbine calculator. The efficiency of a wind turbine depends on factors such as wind speed, blade design, wind power, TSR, pitch angle, number of blades, blade tip angle, and tower height. This research evaluates all these factors. In this research, the maximum power coefficient was achieved at 11 m/s. ANSYS fluent software is also used to simulate the design.

Keywords: Horizontal axis Wind turbine, Solid Works Wind design, CFD analysis

Introduction

In order to achieve sustainable development solutions to our environmental problems today, long-term potential actions are required. As a result, renewable energy resources seem to be the most efficient and effective solution. Thus, sustainable development and renewable energy are intimately linked [1]. The total world energy demand is supplied by 14% by renewable energy sources (RES). Energy from renewable sources includes biomass, hydropower, geothermal, solar, wind, and marine energy. Energy sources from renewable sources are domestic, clean, and inexhaustible [2]. In response to the growing market for renewable energy, innovation is resulting in alternative methods of generating energy. There are many developing countries using renewable energy sources already, making a positive impact on the world [3]. In addition to being a developing country, Pakistan has tremendous potential to generate electricity from solar and wind sources. It is estimated that Pakistan's current electricity needs can be met with solar photovoltaic (solar PV) generation on 0.071 percent of the country's area. It is also difficult to find a more abundant resource than wind. In 10 percent of its windiest areas, Pakistan has average wind speeds of 7.87 meters per

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second. In Pakistan, however, the installed solar and wind energy capacity is just over 1,500 megawatts, or about 2 percent of the total capacity [4]. Approximately 346000 MW of net wind power is expected to be installed across the nation. A number of Pakistan's provinces have tremendous potential for wind power, especially KPK, Sindh, and Baluchistan. When considering how the turbine rotates, two kinds of wind turbines can be distinguished based on the mechanism. However, the direction of the propeller differs between them. It is the vertical axis wind turbines that rotate, while the horizontal axis wind turbines are the ones that spin about the horizontal axis [5].

The main objective of this research is to design a horizontal axis wind turbine that will meet the energy demands of Pakistan. Warlock wind calculator is utilized to test wind power, tip speed ratio (TSR), pitch angle, blade tip angles, blade number, blade design, and tower height of wind turbine. The maximum design velocity is 11 m/s. Simulation software ANSYS Fluent verifies the designed values and calculations for current research.

Design and Calculation

Wind turbines use variable swept areas to increase their efficiency, which is about 59% according to Betz law.

Table 1: The parameters utilized to generate the desired wind turbine model [6, 7]

Generator	**Type** **Maximum power** **Rated power**	**Permanent Magnet** **20KW** **18KW**
Rotor	Configuration No. of Blades Blade Material Blade Length Rotor Diameter Swept Area Rotor Speed	Horizontal Axis 3 Glass fiber 4.5m 9.8m 75.4m 120 rpm
Wind	Cut In speed Rated wind speed Cut Out speed Survival speed	2 m/s 11 m/s 30 m/s 70 m/s
Weight	Nacelle/Rotor	1,000 kg
Tower	Height Material Wind	60 ft. Stainless steel Upwind

Wind turbines generate electricity with a power coefficient that measures their efficiency and can be calculated as;

$$C_P = \frac{P}{\frac{1}{2}*A*\rho*V^3}$$

1. For V = 9.5 m/s

$$C_P = 0.50$$

2. For V = 10 m/s

$$C_P = 0.43$$

3. For V = 11 m/s

$$C_P = 0.032$$

Wind power can be calculated as;

$$P = \frac{1}{2}\rho A V^3$$

Effect of wind direction:

1. For V = 9.5 m/s

   P = 39.7 kW

2. For V = 10 m/s

   P = 46.3 kW

3. For V = 11 m/s

   P = 61.71 kW

Output power can be calculated as;

$$P = \frac{1}{2} C_P \rho A V^3$$

At different values of C_P

1. For V = 9.5 m/s

$$C_P = 0.50$$

P = 19.88 kW

2. For V = 10 m/s

$$C_P = 0.43$$

P = 20 kW

3. For V = 11 m/s

$$C_P = 0.032$$

P = 19.75 Kw

Simulation Analysis

In order to achieve maximum lift, the airfoils are designed for turbines size 20 KW with variable pitch and speed control. Wind turbine blades are designed based on the NACA 63-415 airfoil as illustrated in the figure 1. Software such as SOLID WORKS 2021 has been used to design 20KW power generation wind turbine blades using NACA 63-415 airfoils.

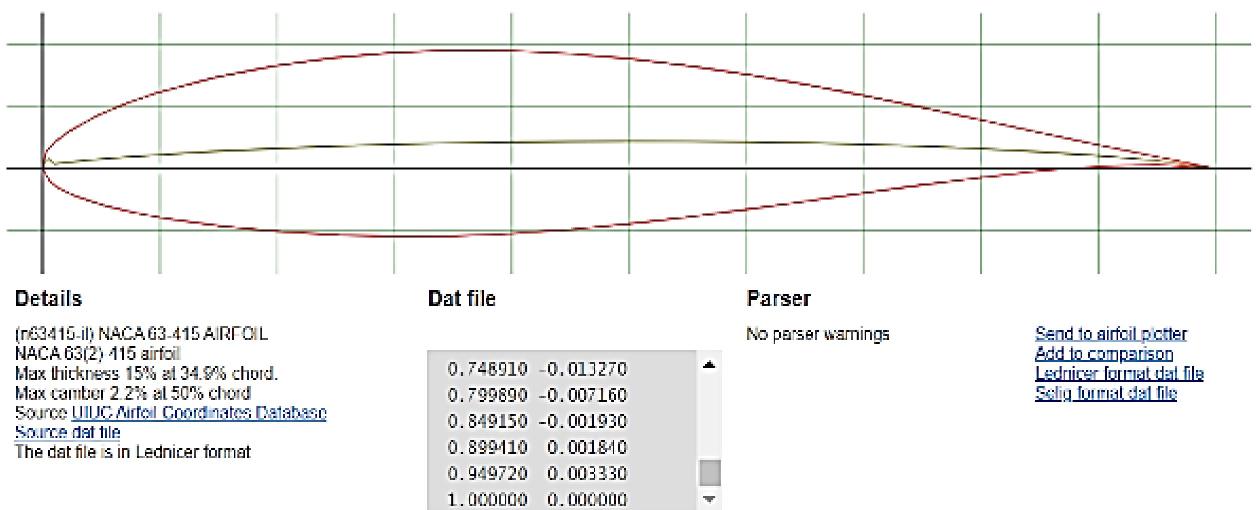

Fig. 1: NACA 63-415 airfoil

With meshing, accurate results can be achieved more quickly. During the meshing process, the physical appearance of the model is taken into account. The element order is linear, and the element size is 0.15 mm.

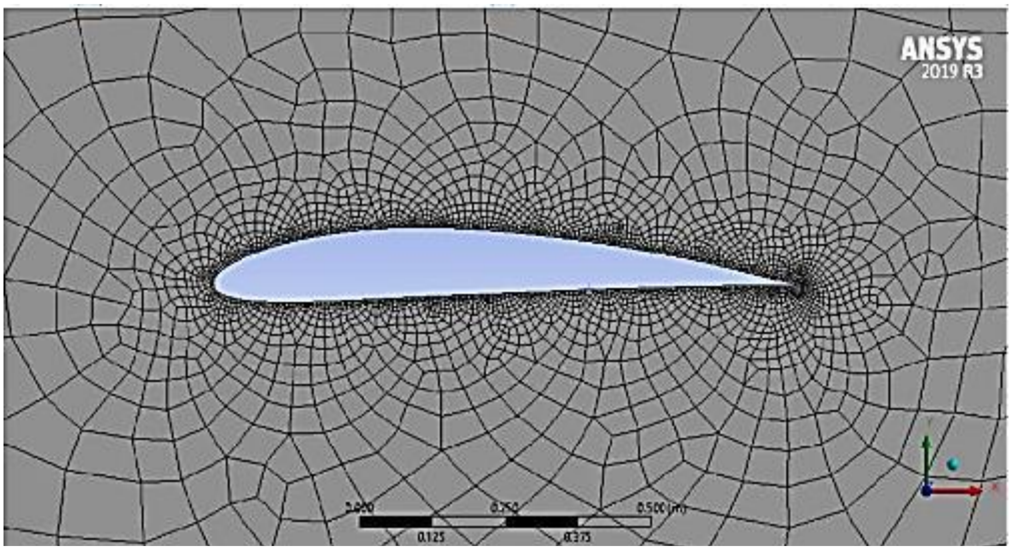

Fig. 2: Refined meshing of airfoil

Fine meshes are formed and irregular foil shapes are transformed into noticeable volumes to get the accurate results.

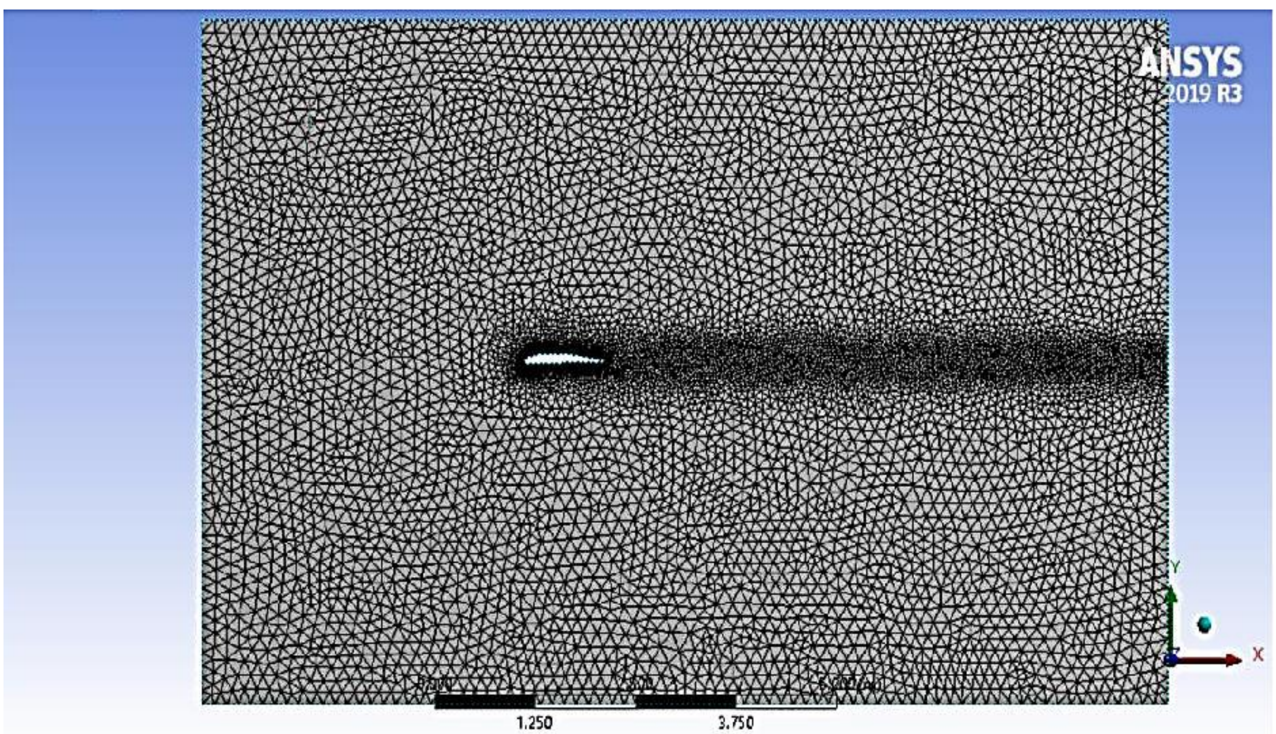

Fig. 3: Accuracy in mesh size

An object's resistance in a fluid can be measured using Drag Coefficients (Cd). Using Ansys 2019R3, the drag coefficient (Cd) for the wind blade of the airfoil can be calculated.

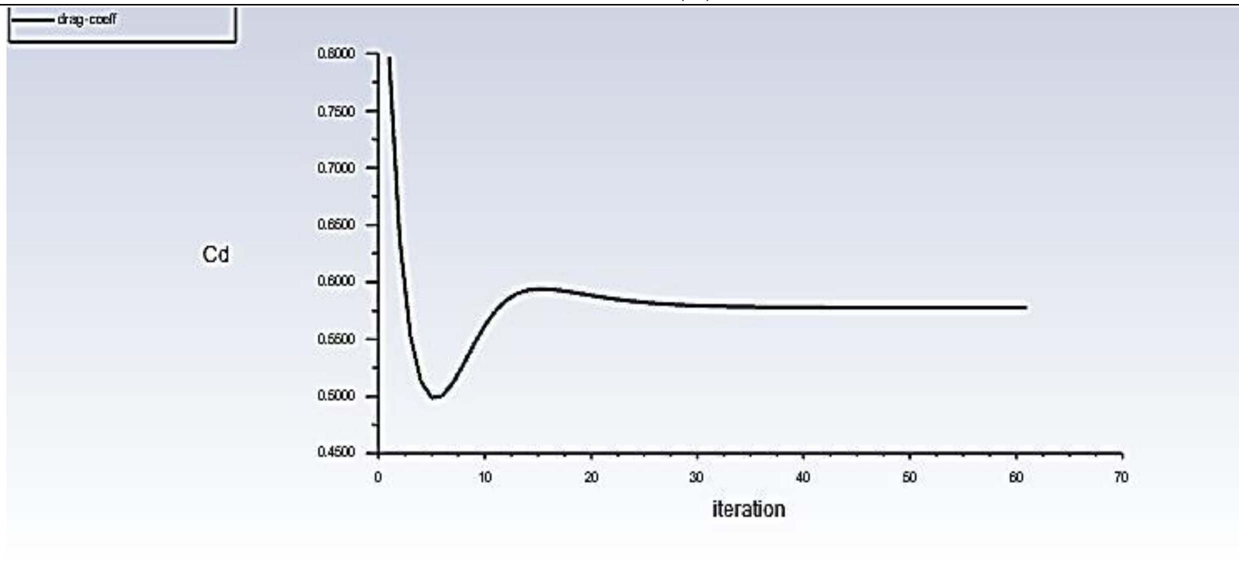

Fig. 4: Drag Coefficient

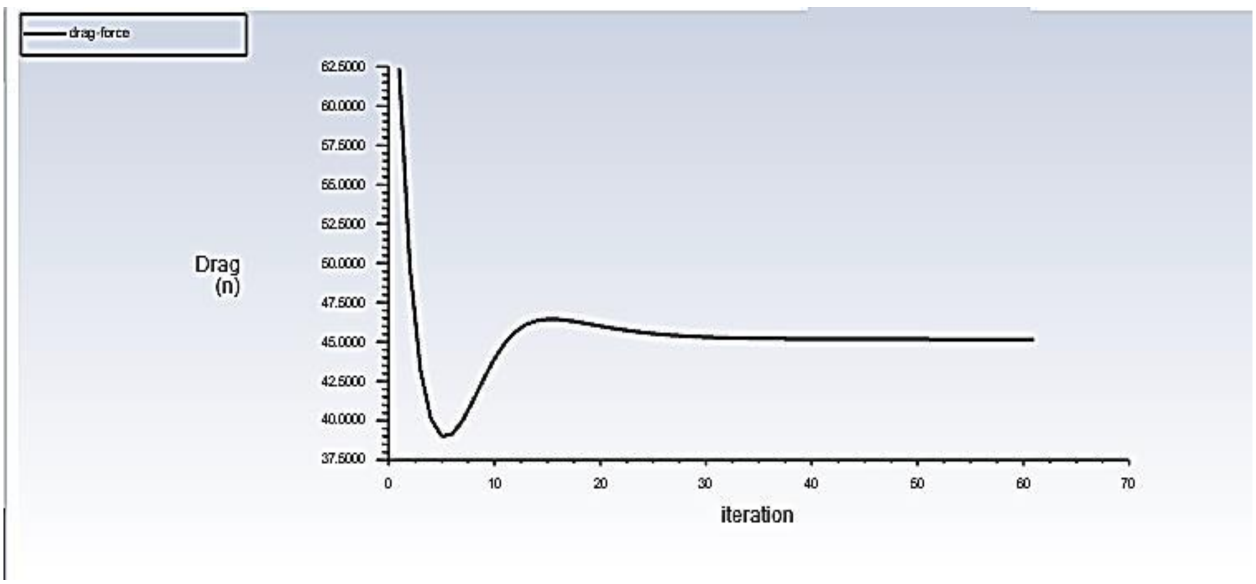

Fig. 5: Drag Force

Lift coefficients show how object shape affects lift. As a result of using ANSYS 2019R3, we can calculate the lift coefficient (Cl) of the airfoil's wind blade as shown in the Figure 6.

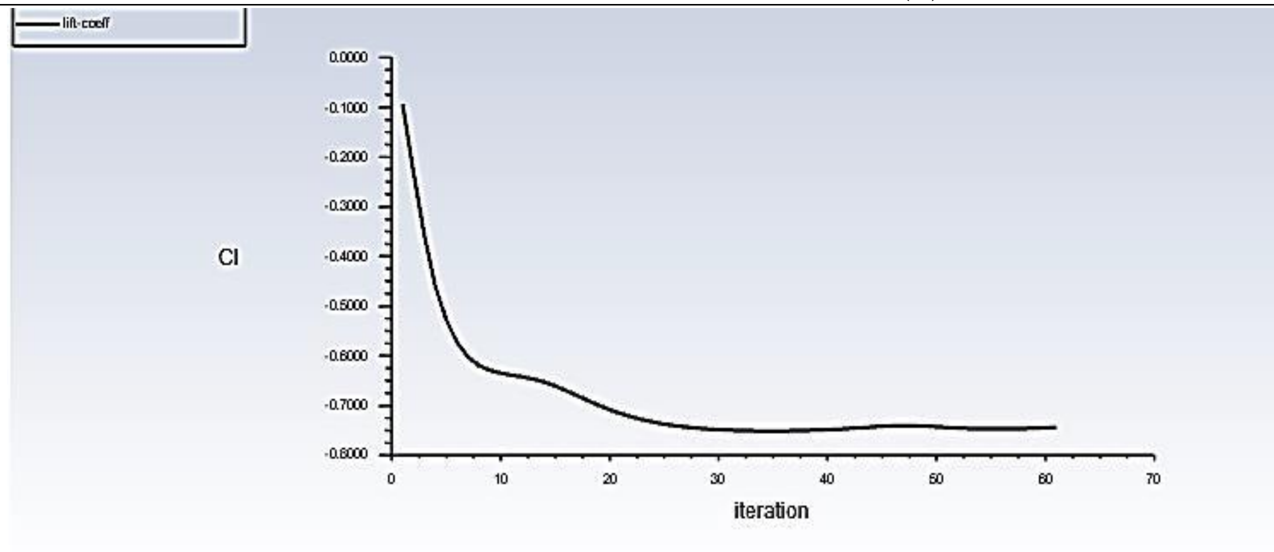

Fig. 6: Lift Coefficient

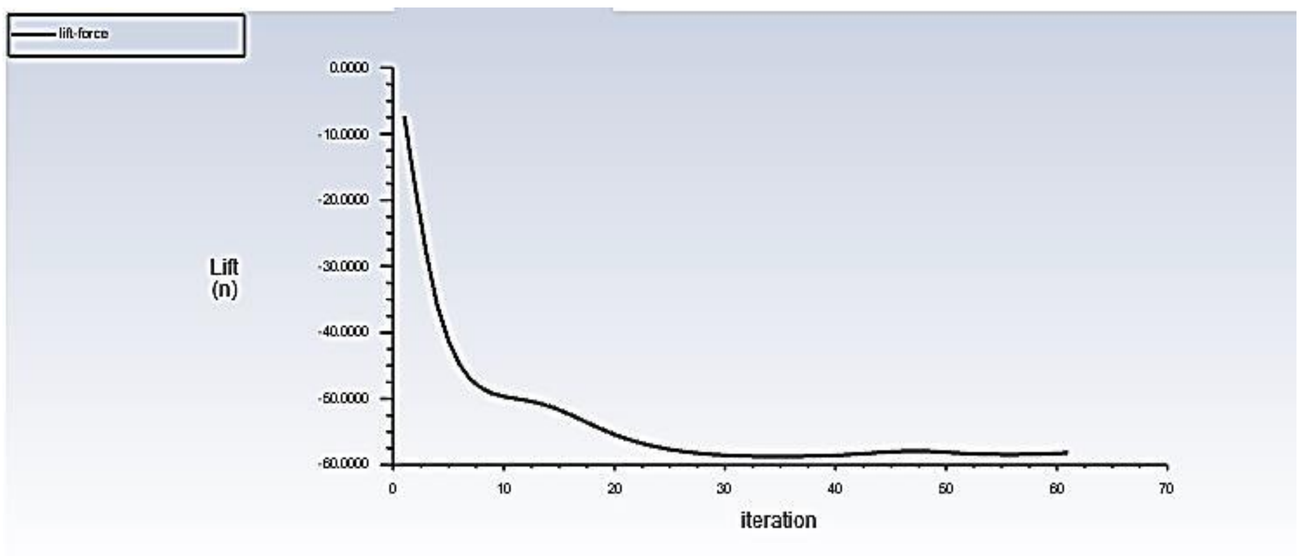

Fig. 7: Lift Force

Mesh elements can be solved by creating nodes between their intersection points. A total of 3659907 nodes are involved in the meshing process. Using SOLIDWORKS 2021, a computational fluid dynamics (CFD) analysis of 3 blades is also conducted to justify the proposed design. With the whole model, flow distributions can be analyzed.

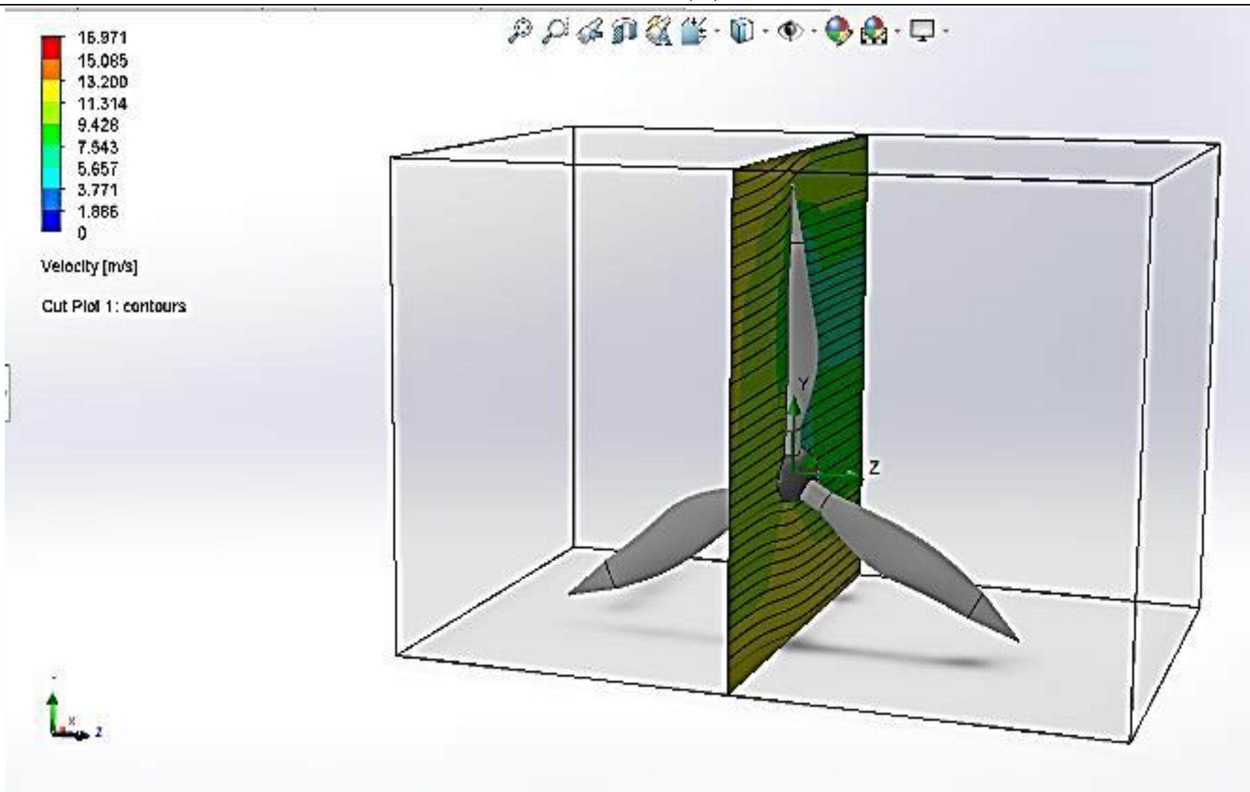

Fig. 8: Velocity Distribution

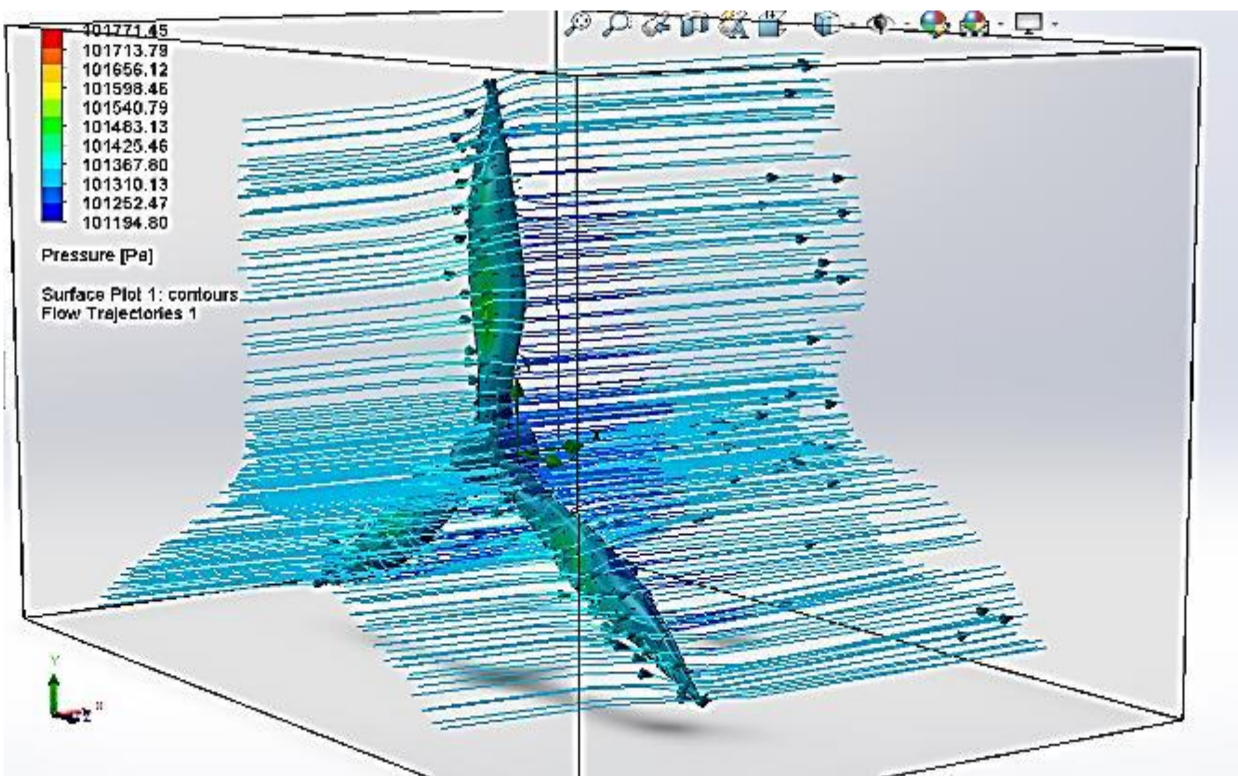

Fig. 9: Pressure Contours

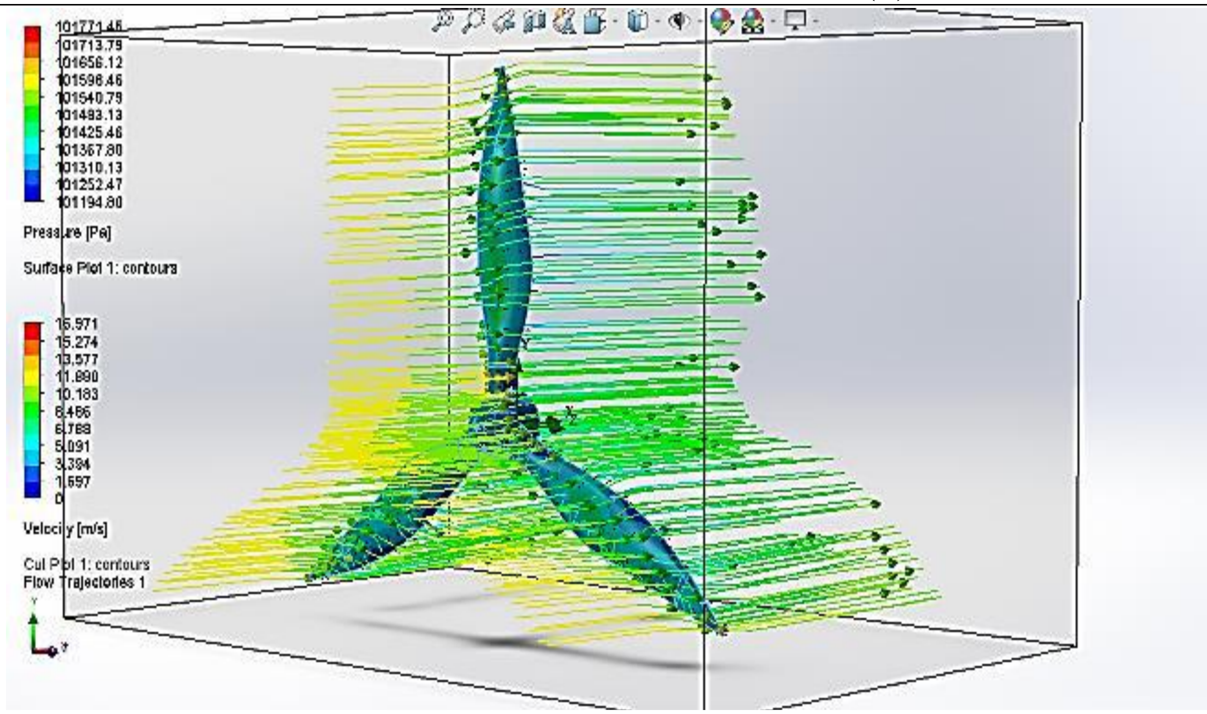

Fig. 10: Velocity Contours

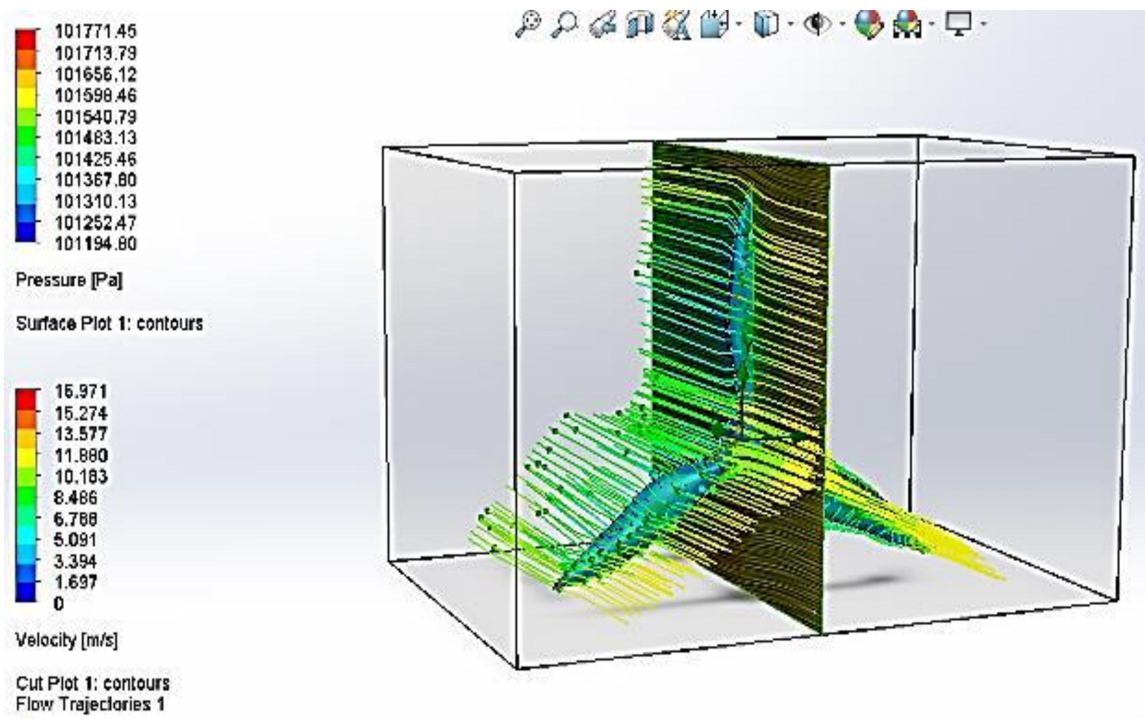

Fig. 11: Surface Plots

The pressure distribution is being taken from the front view to observe the pressure variation on the blade of the designed model.

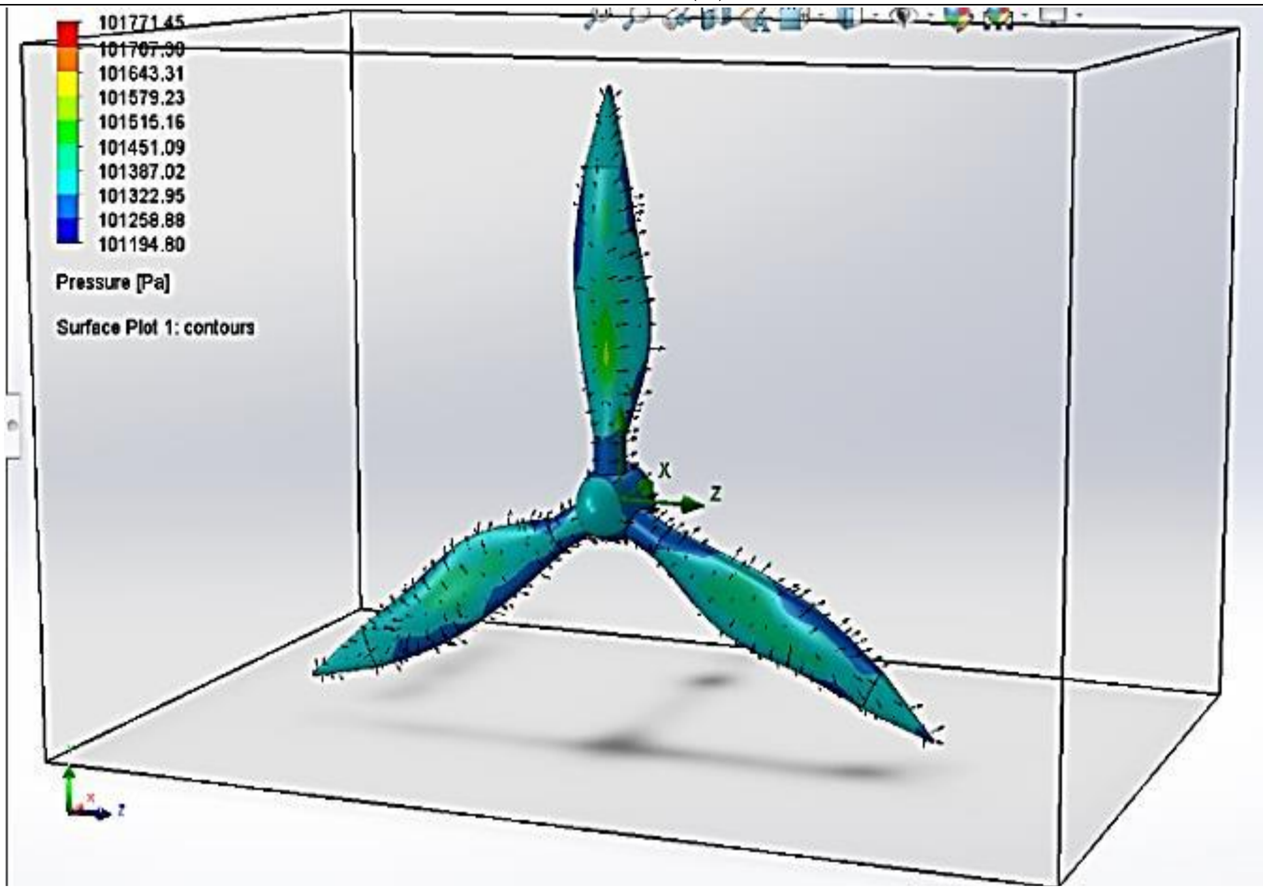

Fig. 12: Pressure Distribution

Conclusion

The current research has proposed a design for HAWT to satisfy the energy needs at the microscopic level in Pakistan. The energy that is produced is very cheap and environmentally friendly. Warlock wind calculator is utilized to test wind power, tip speed ratio (TSR), pitch angle, blade tip angles, blade number, blade design, and tower height of wind turbine. The maximum design velocity is 11 m/s. Simulation software ANSYS verifies the designed values and calculations for current research results. The proposed design may be useful in the future for further analyses in the wind energy disciplines.

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