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Hybrid Power System

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Abstract: ***Energy is one of the most important factors in the country's development and advancement. Several developed countries are facing issues in the production of energy. When we come to electricity, it is the most important source for running all kinds of machinery and industries. Across the world thermal power production is the most commonly used method. But it causes a lot of pollution and many resources are consumed. To avoid all these issues, the world is looking for the best renewable energy sources like wind, solar power productions. This project mainly focusses on design of an integrated setup of wind turbine and solar panel to form a hybrid energy source which is installed over the pole. When it's sunny outside, wind energy can be used to illuminate solar panels, and wind energy can also be used at night and on cloudy or rainy days. Together, the two processes produce a significant amount of electric energy, which solar cells store for use as nighttime lighting . We considered the mono crystalline solar panels(The required no. of cells would be based on the application part) such that the capacity lies between 260-280W. We made sure that the solar inverter capacity would be around 200W. We have chosen the wind turbine generator of 60W capacity. Accordingly, we have considered the solar battery of 12V. And finally, a converter which converts DC to AC.***

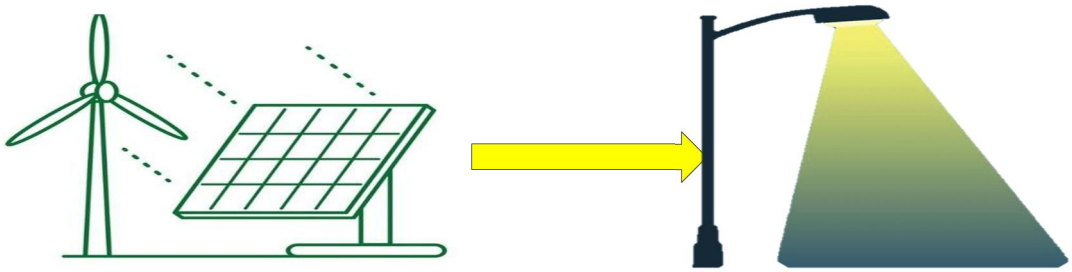
Keywords: Hybrid energy, wind energy, solar energy, CAD, Ansys Analysis.

I. INTRODUCTION

Energy is one of the most important factors in the country's development and advancement. Several developed countries are facing issues in the production of energy. When we come to electricity, it is the most important source for running all kinds of machinery and industries. There are many ways to produce electricity like thermal production, hydro power production, solar power production, wind power production and in some areas geothermal power production. Across the world thermal power production is the most commonly used method. But it causes a lot of pollution and many resources are consumed. To avoid all these issues, the world is looking for the best renewable energy sources like wind, solar power productions. There were many solar and wind power stations. Lights are one of the major power consumption devices in any country. From any power station to street lights during many transmissions there were many power losses. To tackle these issues there were solar panel setup over the street light pole to generate the power for those individual poles. To extract more renewable energy there were many hybrid sources of power production concepts. Hybrid means wind turbines and solar panel to extract power from wind and light respectively.

The term “Hybrid Power System" refers to a system in which solar and wind energy are used as power generation elements to simultaneously charge an energy storage battery and provide electricity for a corresponding LED light. When it's sunny outside, wind energy can be used to illuminate solar panels, and wind energy can also be used at night and on cloudy or rainy days. Together, the two processes produce a significant amount of electric energy, which solar cells store for use as nighttime lighting. The controller manages the light source on time and keeps the battery from being overcharged or discharged.

When we look at wind turbines mainly HAWT and VAWT. HAWT has more power coefficient compared to VAWT. system consists of solar panel, wind turbine, charge controller, converter and cables along with led lights. The limitations of HAWT like noise and area for installation and the maintenance forced to shift to VAWT. It requires less space and easy installation, design and maintenance. But it has less power coefficient than HAWT, it doesn’t require yam and pitch system.



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A. Types of Wind Turbines

There are two main types of wind turbines:

1) *Horizontal Axis Wind Turbines (HAWTs):* These turbines have blades that rotate around a horizontal axis. They are usually large and can produce a lot of power. The performance of HAWTs is affected by various factors, such as wind speed, air density, blade length, and blade pitch angle. HAWTs are typically designed to operate at wind speeds between 10 and 25 meters per second. If the wind speed is too low, the turbine will not generate enough electricity, while high wind speeds can damage the turbine and reduce its lifespan. HAWTs are further classified into two types:

- *Upwind Turbines:* These turbines have the rotor facing into the wind and are more common.
- *Downwind Turbines:* These turbines have the rotor facing away from the wind and are less common.

2) *Vertical Axis Wind Turbines (VAWTs):* These turbines have blades that rotate around a vertical axis. They are usually smaller in size and have a lower capacity than larger turbines. The performance of VAWTs is affected by various factors, such as wind speed, blade length, and blade pitch angle. Unlike HAWTs, VAWTs can operate effectively in turbulent wind conditions, making them suitable for urban and suburban areas where wind conditions can be highly variable. Overall, VAWTs offer several advantages over HAWTs, including their compact size, suitability for low wind speeds, and ability to operate effectively in turbulent wind conditions. However, they typically have a lower capacity and are less efficient than HAWTs, making them better suited for small-scale applications. VAWTs are further classified into two types:

- *Savonius Turbines:* These turbines have a curved blade design and are suitable for low wind speeds.
- *Darrieus Turbines:* These turbines have a straight blade design and are suitable for higher wind speeds.

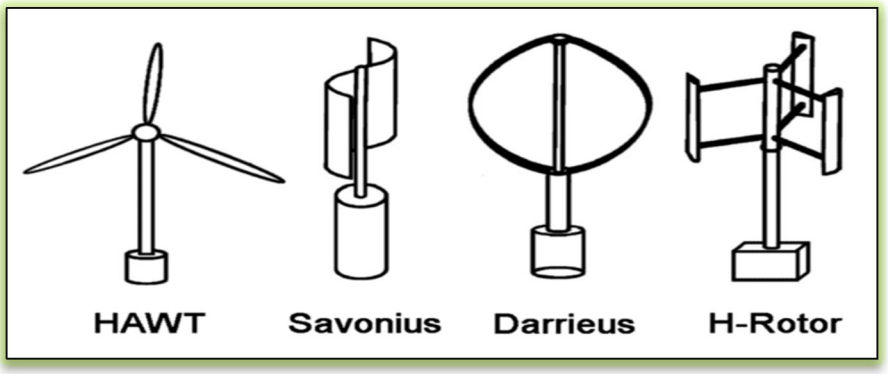


Fig 1: Types of Wind Turbines

B. Comparison Between HAWT and VAWT

S.No	Performance	HAWT	VAWT
1	Power Generation	50% - 60%	Above 70%
2	Electromagnetic interference	YES	NO
3	Steering Mechanism of Wind	YES	NO
4	Gear box	Above 10KW: Yes	NO
5	Blade Rotation Space	Quite Large	Quite Small
6	Wind-Resistance Capability	Weak	Strong
7	Noise	5-60dB	0-10dB
8	Starting wind Speed	High	Low
9	Failure Rate	High	Low
10	Maintenance	Complicated	Convenient
11	Rotating Speed	High	Low
12	Effect on Birds	High	Low
13	Cable Stranding Problem	YES	NO
DECISION		**Rejected**	**Selected**

Table 1: Comparison between HAWT & VAWT
Source: https://www.sciencedirect.com/science/article/pii/S1877705812047741

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1) Vertical Axis Wind Turbine (VAWT) is a Preferred over a Horizontal Axis Wind Turbine (HAWT).

Ultimately, the choice between a VAWT and a HAWT will depend on a variety of factors, including wind conditions, available space, noise considerations, and the specific needs of our project.

Firstly, VAWTs can operate effectively at lower wind speeds than HAWTs, making them suitable for areas with weaker wind conditions. This makes them a good choice for smaller-scale applications such as residential or small commercial use. Secondly, VAWTs are typically smaller in size than HAWTs, which can make them easier to install and maintain. This can be an advantage in areas where space is limited, such as urban or suburban locations.

Thirdly, VAWTs generally produce less noise than HAWTs, making them a better option for residential areas. Fourthly, VAWTs are often considered more visually appealing than HAWTs, making them a good option for locations where aesthetics is a consideration. Fifthly, VAWTs can operate effectively in turbulent wind conditions, which can be an advantage in urban or suburban areas where wind conditions can be highly variable. Lastly, VAWTs do not pose the same risk of injury to wildlife, such as birds, as HAWTs, as their blades rotate around a vertical axis.

C. Types of Solar Panels

1) *Monocrystalline Solar Panels:* When a solar panel is composed of monocrystalline solar cells, it is known as a monocrystalline solar panel. The panel's name is derived from the cylindrical silicon workpiece used, which is made of highly pure single crystal silicon. The single crystal process used to create the cells gives electrons more space to move, resulting in a better electrical flow. To produce the cells, thin films are sliced from the cylindrical workpiece and cut into circular chips, which are then wire-cut into an octagonal shape to optimize the cell's usage. The distinctive appearance of these cells is due to their octagonal shape.
2) *Polycrystalline Solar Panels:* Polycrystalline or multicrystalline solar cells are made up of several silicon crystals in a single PV cell. The plates used to create polycrystalline solar panels are produced by melting multiple silicon pieces together. In this case, the molten silicon pool used to create the cells is allowed to cool directly on the panel surface. These solar panels have a distinctive appearance, with a surface pattern consisting of many polycrystalline silicon crystals. They are square in shape and have a brilliant blue color, making them easily recognizable.
3) *Thin Film Solar Panels:* Thin-film solar panels require less semiconductor material during production compared to traditional crystalline silicon modules, yet they have similar performance in terms of the photovoltaic effect. The semiconductor in thin-film PV modules moves as a result of this effect, producing an electric flow that can be converted into usable electricity by an external circuit. Strong light-absorbing materials such as cadmium telluride (Cd-Te), copper indium gallium selenide (CIGS), amorphous silicon (a-Si), and gallium arsenide (GaAs) are commonly used in the manufacture of thin-film solar panels, making them an ideal choice for solar energy production.
4) *Concentrated PV Solar Panels:* Concentrated photovoltaic (CPV) technology utilizes lenses or curved mirrors to concentrate a significant amount of sunlight into a small region of solar photovoltaic (PV) cells to generate electricity. CPV systems require less photovoltaic material than non-concentrated photovoltaics, resulting in lower solar cell costs.

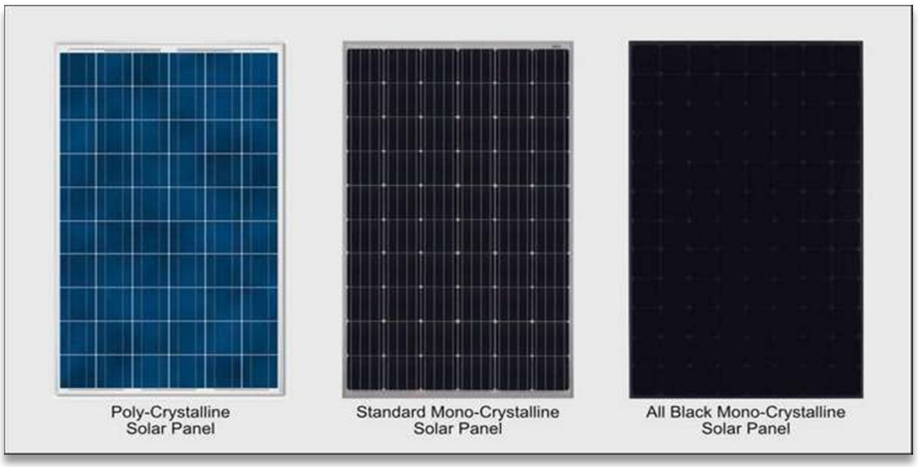


Fig 2: Types of Solar Panels

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D. Comparison Between Solar Panels

Solar Cell Type	Efficiency Rate	Advantages	Disadvantages
Monocrystalline Solar Panels (Mono-SI)	~20%	High efficiency rate; optimised for commercial use; high life-time value	Expensive
Polycrystalline Solar Panels (p-Si)	~15%	Lower price	Sensitive to high temperatures; lower lifespan & slightly less space efficiency
Thin-Film: Amorphous Silicon Solar Panels (A-SI)	~7-10%	Relatively low costs; easy to produce & flexible	shorter warranties & lifespan
Concentrated PV Cell (CVP)	~41%	Very high performance & efficiency rate	Solar tracker & cooling system needed (to reach high efficiency rate)

Table 2: Comparison between Solar Panels
Source: https://www.greenmatch.co.uk/blog/2015/09/types-of-solar-panels

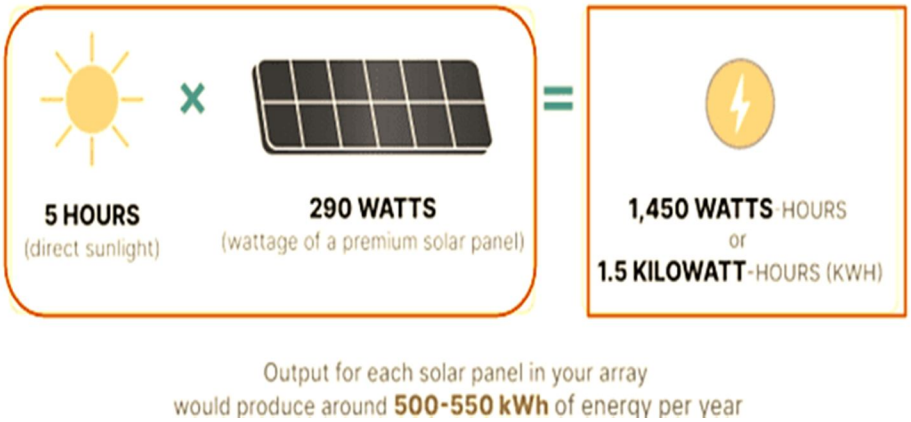
1) Power Generation in Solar Panels

Power production is a crucial measurement. The cost of a solar photovoltaic (PV) energy system depends primarily on the system's solar panel output when you purchase or install one. Basically, there are two key factors present which determines the power output of the solar panel. They are:

- Cell efficiency
- Solar panel size

Silicon-based solar cells are capable of converting almost 17 - 22% of incident sunlight into usable solar energy, enabling the production of panels that can generate more than 400 watts of power. Greater efficiency leads to more energy, making high-efficiency solar panels more attractive for home electricity production.

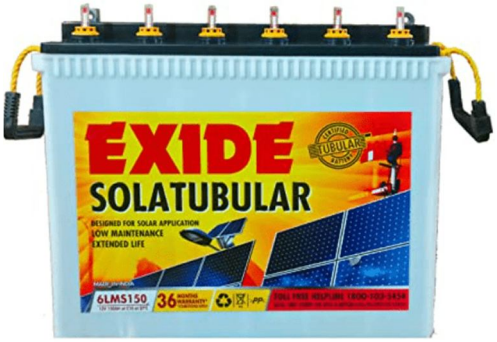
Solar panels come in two sizes, 60-cell and 72-cell categories. Typically, 60-cell solar panels measure 5.4 feet in height and 3.25 feet in width, producing 250 to 300 watts of power. In comparison, 72-cell solar panels produce between 300 - 450 watts and are larger due to the additional row of cells. 72-cell panels are frequently used on large structures and in commercial solar projects, rather than on residential homes. Most of the solar panels produce the power between 200W to 450W.



2) Components



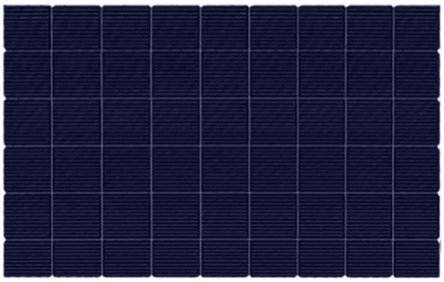
AC – DC convertor



12 V , 150 Ah Solar battery



Generator



Solar Panel

E. Technical Specification of the Components

DIMENSIONS	Panel: 167 x 102 x 6 (in cm) Solar Inverter: 30 x 25 x 20 (in cm) Solar Battery: 18 x 8 x 18 (in cm)
WEIGHT	Panel: 18-20 kg Solar Inverter: 600-650 g Solar Battery: 7-7.5 kg
COST	Panel: 13000-15000 (in rupee) AC-DC convertor: 600-700 (in rupee) Solar Battery: 16000 (in rupee) turbine generator: 3000-3500 (in rupee)
CAPACITY	Panel: 260-280W Solar Inverter: 200W, 220V Solar Battery: 12V ,150Ah Wind turbine generator: 60W
MATERIAL	Silicon, Glass, Metal Generator: Cast Iron

II. LITERATURE REVIEW

The most efficient hybrid source of energy is solar with wind turbine trend in the last 25 years in renewable energy sources[13]. There were mainly two types of wind turbine named Horizontal axis wind turbine(HAWT) and Vertical axis wind turbine(VAWT). It is noted that VAWT has few advantages like low noise, independent of wind direction, and easy maintenance of all parts because it is lower to ground compared to HAWT, and doesn't need a pitch and yam system[12][3]. In the presence of solar radiation PV modules generate power, likewise due to movement in wind turbines that rotate and generate power. Integration of both wind and solar with help of Wind-solar hybrid intelligent controller (model: EPFG24V-20)[16]. In VAWT category It is noted that helical turbines give stable torque and higher power coefficient when compared to traditional Savonius turbines, despite having complex construction processes[17].

When we come to material selection for the designed parts, we need metal which needs to be good in strength and lightweight materials. When light weight and strength comes into picture ,For upper hand we consider light weight material as main factor when compared to strength because the upper hand just needs to support and stabilize the turbine, it will not hold any weight. So, Aluminum Alloy is the suitable material. Steel can be three times the weight of aluminum for two pieces of similar volume[1]. For the Lower hand we considered strength as the main factor because it needs to hold the turbine and generator. So steel is a suitable material[1]. For center pole steel is a suitable material, as it needs to bear the weight of all components. When we come to the dimension of the center pole, it's around 2-15 meters height, for our design we consider it as 3 m height [2][3].

Here the authors have considered the automated street light system where it is doesn't require any human assistance(21). The authors worked on the development of the standalone street light considering the supply performances and the energy requirements(22). The analysis of street light system proven that there would be an improvement of power supply and control in economic related activities(23). Covered all aspects of the transition from conventional, environmentally damaging energy sources to hybrid wind solar renewable energy systems for highway lightning(24). Contrasts the individual modelling and integration of a wind and solar power system carried out in MATLAB with the load analysis of a hybrid solar wind system(25).

The primary goal of this essay was to highlight the importance of developing smart systems for secure urban environments(26). Wind solar hybrid street lights static analysis reveals that it's overall construction could meet the requirements for strength and stiffness(27). Demonstrated a new adaptive system that combines a vertical "SAVONIUS" type wind turbine and a hybrid renewable energy system fir street light that use solar energy(28). A hybrid energy solution is employed, together with a freestanding, manual system for emergency e-vehicle charging, and the street lighting system(29). Challenges with freestanding PV systems were addressed in this research by a grid-connected PV system that employed HOMER Pro and Matlab/Simulink(30).

III. GAPS IN LITERATURE REVIEW

1) In a few research papers they claimed that hybrid power generation is good and efficient power generation when compared to a single source of power. But there were different concepts and combinations in the hybrid system. After the literature review, we came up with the combination of two VAWT with PV module with a new design that can be fixed over the pole.
2) Almost in every research they fixed the entire system in a fixed manner, but there was no design in which they could remove the turbine and fix another turbine for any maintenance or repair.
3) The effect of Blade configuration of the wind turbine on the performance of the street light was not mentioned in detail.
4) In the street light concept, research is done with a single turbine fixed with PV module, but this research is on comparison of feasibility of two different turbines (VAWT) along with PV module and two same turbines with PV module

IV. PROBLEM DEFINITION

The power system in its current state is facing multiple challenges that impact its reliability, efficiency, and sustainability. One of the biggest issues is the growing demand for electricity and the aging infrastructure that was designed to distribute power from large centralized plants to customers via a network of transmission and distribution lines. Integrating renewable energy sources into the grid, including solar panels, wind turbines, and energy storage systems, has led to the emergence of a decentralized and dynamic power system known as a smart grid. In addition to these technical and economic hurdles, the current power system is also facing environmental challenges due to the use of fossil fuels, which are the primary cause of greenhouse gas emissions. Transitioning to a low-carbon economy requires significant investment in renewable energy technologies, energy storage, and grid modernization, all of which entail substantial upfront costs. Therefore, the current power system is tasked with balancing the trade-offs between cost, reliability, and sustainability while ensuring equitable access to electricity for all. The success of the power system will require the development of innovative solutions to address these challenges and ensure a sustainable and reliable energy future.

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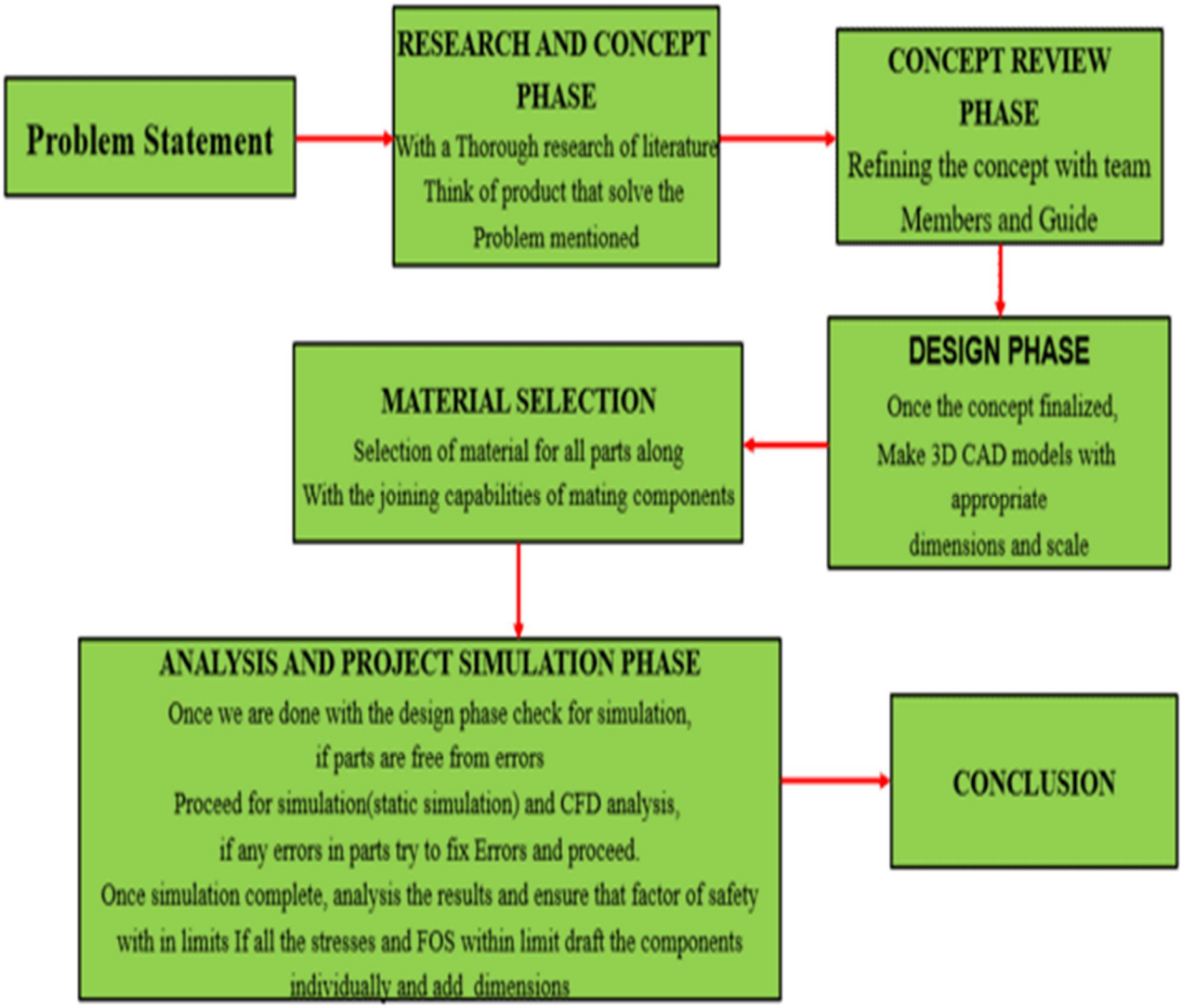
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V. OBJECTIVES

1) Design the hybrid street light equipped with two wind turbines and PV module along with the LED light and pole.
2) Compare different types of wind turbines (VAWT) with different parameters.
3) Identifying suitable Material for the product , also estimating cost for manufacturing our components considering all the factors
4) To find the torque and power generated by hybrid system.
5) To find how extent solar panel will affect the turbine power generation

VI. METHODOLOGY

Our first step is to define the project goals and objectives. Identify the specific requirements for the hybrid power system, such as the power demand, energy storage capacity, renewable energy sources, and the backup system. This step will also involve setting the project scope and defining the project timeline. Next Conduct a site assessment to identify the local conditions, such as the climate, terrain, and available renewable resources. Determine the feasibility of the project and the potential for integrating renewable energy sources into the hybrid power system. This step involves selecting the appropriate renewable energy technologies, such as solar panels, wind turbines, or hydroelectric generators, and the energy storage system, such as batteries or fuel cells.
Finally, the hybrid power system's performance should be evaluated regularly to identify any areas that need improvement. This step involves analyzing the system's efficiency, reliability, and cost-effectiveness and optimizing the system design and operation accordingly, based on the results of the Ansys analysis.



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VII. CAD AND CAE

A. CAD Modeling

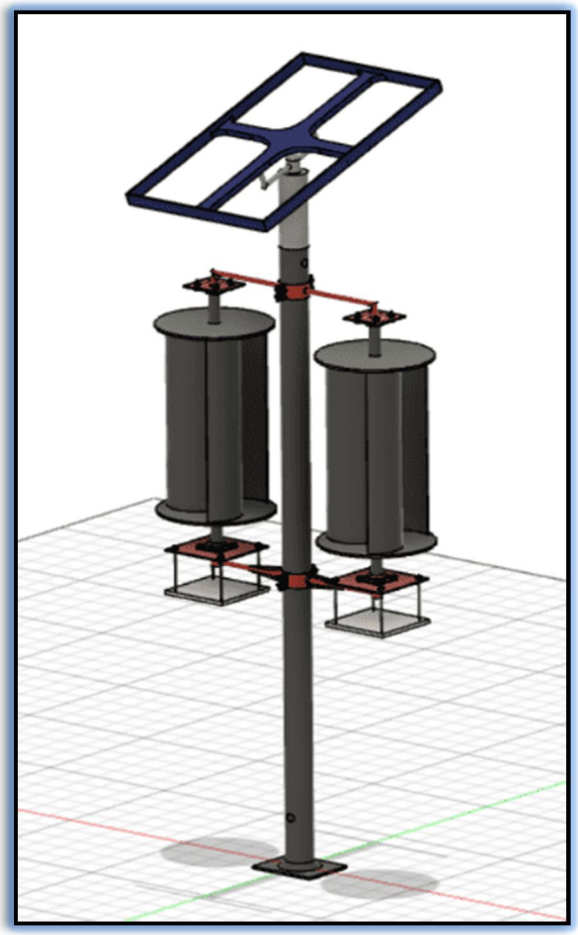


Fig 3: CAD model of Hybrid Power System

The Hybrid Power System CAD model is developed in Fusion 360 software in a detailed and accurate representation. The model comprises a pole, which acts as a support structure for the entire system, two VAWT Savonius turbines, Solar Panel, and many other small components.

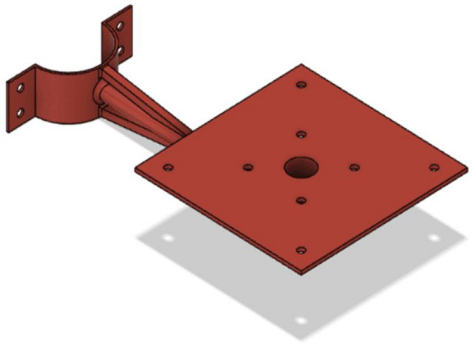
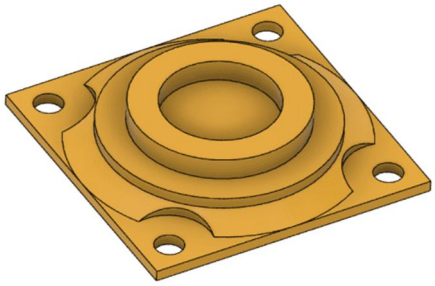
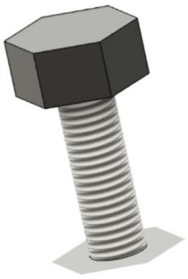
The pole is designed to withstand the weight of the turbines and other components, as well as the wind load on the turbines. It has a circular cross-section and is tapered towards the top, to reduce wind resistance. The pole is modeled with various features such as anchor bolts, flange plates, and brackets, which allow for easy installation and maintenance.

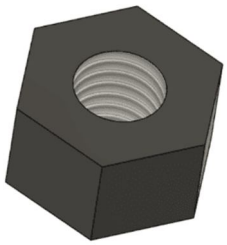
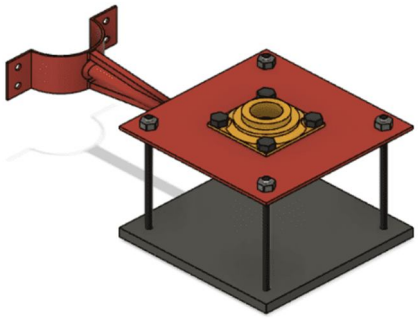
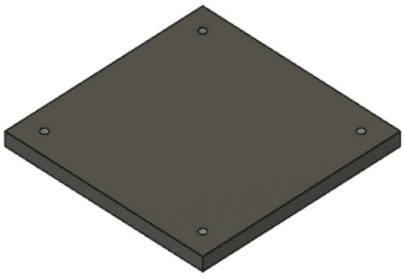
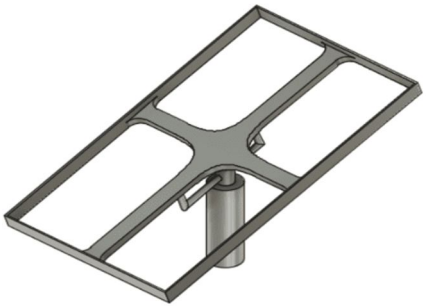
The VAWT Savonius turbines are designed to capture wind energy efficiently, using the principle of drag. The turbines are positioned on opposite sides of the pole to ensure maximum wind capture. The turbines have a curved shape, consisting of two semi-circular blades with a scoop on one side and a flat surface on the other. The blades are designed to rotate in response to the wind, driving the generator to produce electricity. The model also includes the shaft, bearings, and other components necessary for the turbines' operation.

In addition to the pole and turbines, the CAD model also includes many other small components, such as brackets, bolts, and clamps. These components are essential for the system's stability and performance and are accurately modeled to ensure their proper fit and function. Overall, the Hybrid Power System CAD model developed in Fusion 360 software is a highly detailed and accurate representation of the actual system. The model allows for easy visualization and analysis of the system's design and performance, enabling designers and engineers to optimize the system for maximum efficiency and reliability.

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1) Components

Name	*Model*
Pole	
Lower Hand	
Bearing Holder	
Bolt	

Nut	
Rod	
Upper Hand	
Plate	
Panel Holder	

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2) Material Analysis

Part	Quantity	Material	Density (gmm^{-3})	Mass g	Volume (mm^{-3})	Area (mm^{-2})
2 Blade Savonius VAWT	1	Aluminum 6061 T6 0 Cold Formed	0.003	6.976.7	2.584106	1.613106
3 Blade Savonius VAWT	1	Aluminum	0.003	7508.55	2.78106	2.007106
Lower Hand	2	steel	0.008	3462.987	4.411106	2.095105
Upper Hand	2	Aluminum	0.003	520.62	1928105	1.176105
Lower Bearing Holder	2	Iron, Gray Cast ASTM A48 Grade 20	0.007	749.533	1.014105	26357.5
Upper Bearing Holder	2	Iron, Gray Cast ASTM A48 Grade 20	0.007	888.931	1.202105	26985.82
Screw Rod	8	steel	0.008	119.636	15240.25	6341.34
Nut	32	Steel	0.008	22.686	2889.9	1532.2
Bolt	24	Stainless Steel	0.008	46	5750.14	2313.981
Pole	1	Steel AISI 4130 366 QT	0.008	16376	2.086106	1.645106
Panel Holder	1	Steel, High strength, Low Alloy	0.008	13279	1.96506	3.859105
Plate	2	Steel	0.008	2444.161	3.114105	1.301105

3) Static Stress Simulation

The simulation process involves creating a virtual model of the hybrid power system in the Fusion 360 software and defining the material properties, boundary conditions, and loads that the system will be subjected to. The software then uses finite element analysis (FEA) techniques to solve for the stresses, strains, and displacements in the model.

The results of the simulation can be used to identify potential areas of weakness or failure in the system and make design changes to improve its structural integrity. For example, the simulation may reveal that a particular component is experiencing high levels of stress and needs to be redesigned or reinforced to handle the loads. Overall, static stress simulation is a valuable tool for optimizing the design of a hybrid power system and ensuring its reliability and safety.

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Fig 4: Load at the Turbine Location

4) Load Conditions

For the designed model there will be external loads applied. The external loads are the weight of the PV panel, and weight of wind turbines and generators. For simulation with respect to real world dimension and weight we considered weight of PV panel as 200N(approx 20kgs) and weight of generator as 250N (approx 25kgs) and considered gravity in simulation. For turbine weight we considered 100N (approx 10kgs). The loading is shown in given figures.

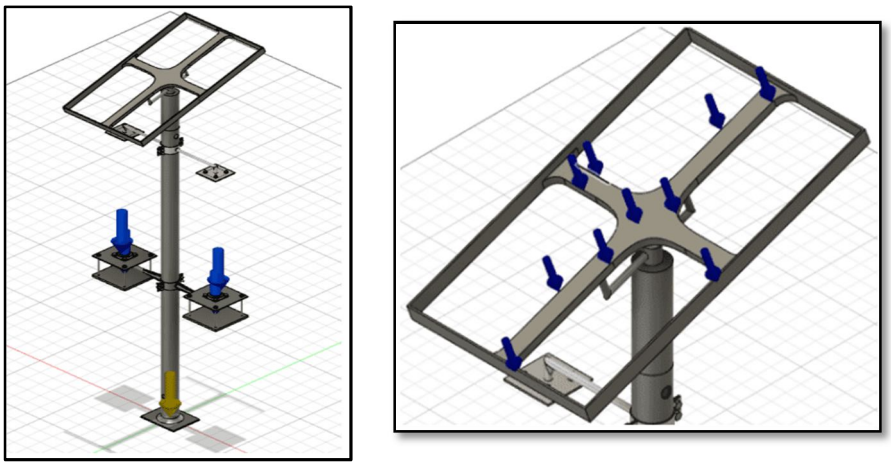


Fig 5: Loading locations

Force-1(at bearing)	
Type	**Force**
Magnitude	100 N
X Value	0 N
Y Value	0 N
Z Value	-100 N
X Angle	0
Y Angle	90
Z Angle	0

Force-2(weight of generator)	
Type	**Force (N)**
Magnitude	250
X Value	0
Y Value	0
Z Value	-250

Force-3 (PV panel weight)	
Type	**Force (N)**
Magnitude	200
X Value	0
Y Value	68.4
Z Value	-187.9

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The load and constraints are critical inputs in a static stress simulation of a hybrid power system CAD model. The load refers to the external forces or moments applied to the system. The load can be uniform or non-uniform, and it can be applied in any direction. The constraints, on the other hand, refer to the restrictions on the motion of the system. These can include fixed supports, sliding or rotational joints, or other types of constraints that limit the degrees of freedom of the model. Overall, the combination of load, constraints, and material properties are key inputs for a static stress simulation of a hybrid power system CAD model. By carefully defining these inputs and analyzing the results of the simulation, designers can optimize the performance and durability of the system while minimizing weight and cost.

5) *Factor of Safety*

When 2 loads are applied i.e., one at lower hand bearing holder part and other at plate beneath the turbine holder bearing(100N) for both hands. It is observed that the model is able to withstand both loads perfectly. It is observed that Factor of safety is 3.425

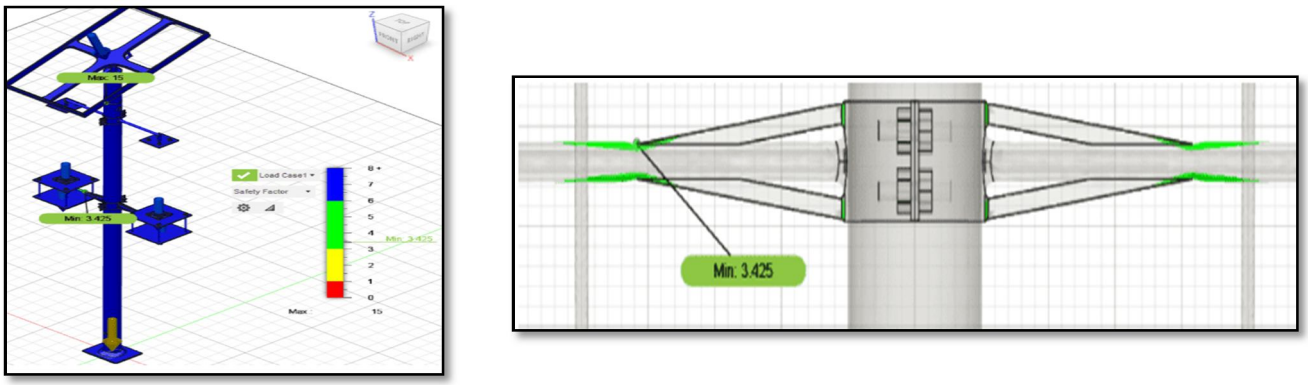


Fig 7: Factor of safety Analysis

6) Stress Analysis

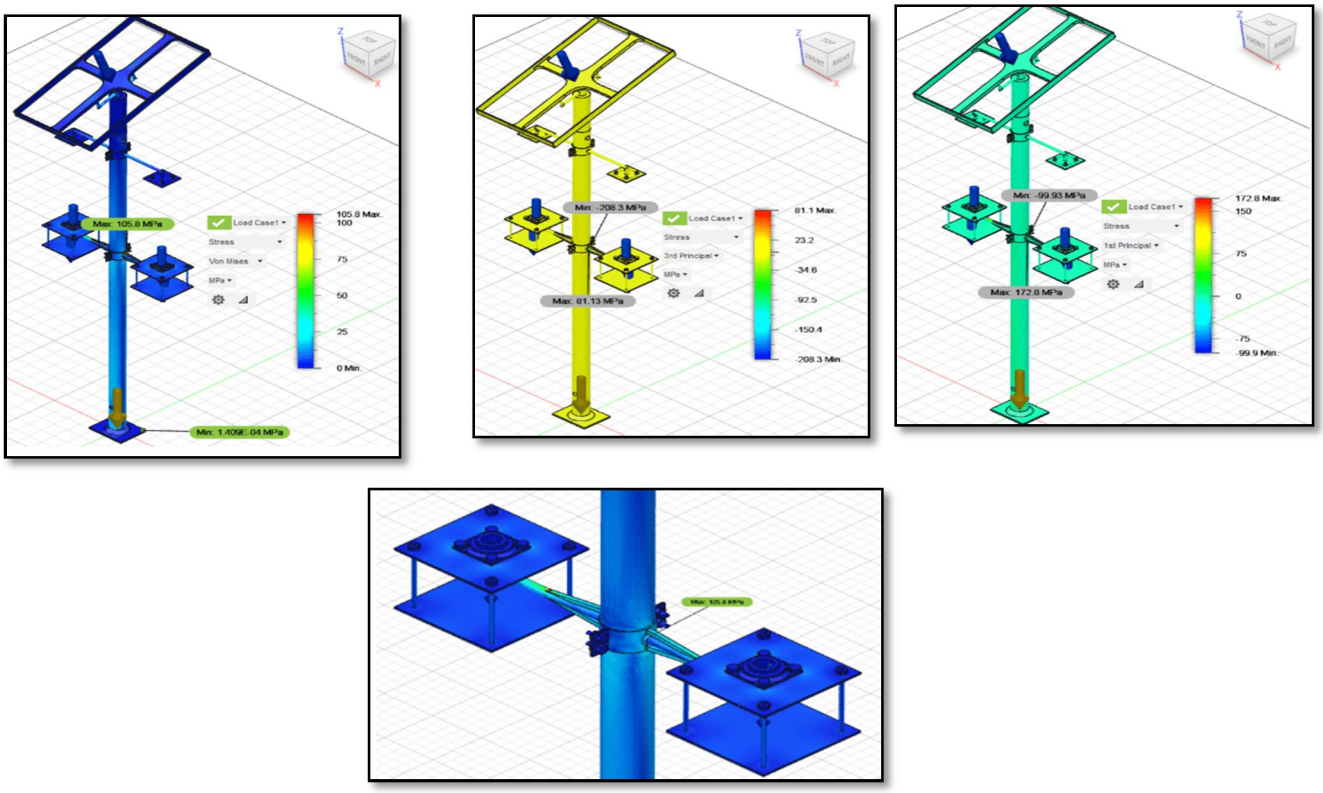


Fig 6: Stress Analysis

With the applied load conditions, we can observe that the maximum stress is 105.8Mpa and the minimum stress is 1.409 10-4MPa. from the analysis we can observe that max stress is at the joining part of lower hand with pole. At lower hand where the support rod is attached, we can observe the stress around 50-60 MPa, this is where the minimum FOS appeared as per loading conditions

Table 3: Stress Analysis data

Stress	Minimum (MPa)	Maximum (MPa)
Von Mises	1.04 10-4	105.8
1st Principal	-99.93	172.8
3rd Principal	-208.3	81.13
Normal XX	-194.6	172.1
Normal YY	-123.3	90
Normal ZZ	-103.2	92.33
Shear XY	-42.7	31.01
Shear YZ	-21.48	11.02
Shear ZX	-16.84	12.87

7) Displacement Analysis

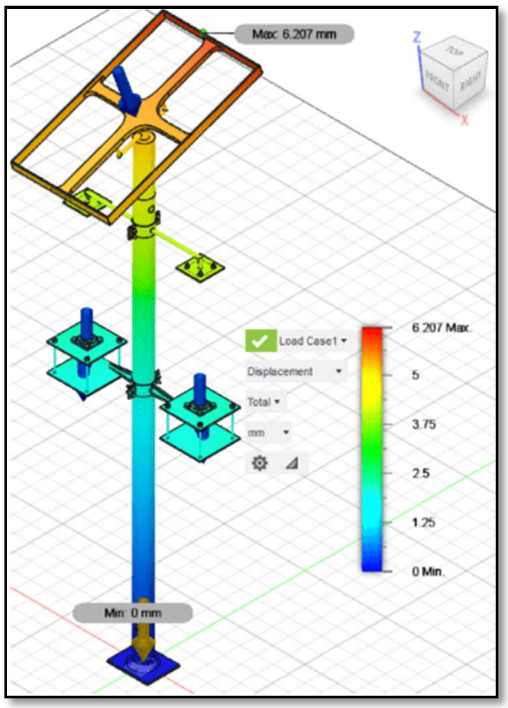
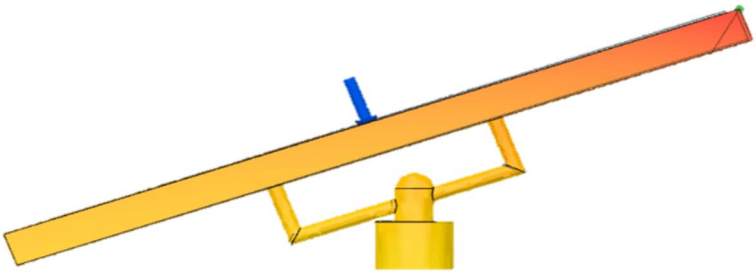


Fig 8: Displacement analysis

Displacement	Minimum (mm)	Maximum (mm)
Total	0	6.207
X	-0.536	0.5264
Y	-5.019 10-4	6.097
Z	-1.493	1.247

When the external loads are applied the maximum displacement that occurred in the design is 6.207 mm which is very minimal in practical life and the least displacement we can observe as 0mm. We can observe that due to the PV panel weight the panel holder has maximum displacement as we go down the design, we can observe the displacement decreases. At upper hand level the displacement is around 3-4 mm. At lower hand level the displacement is around 1-2 mm and at bottom of the pole the displacement is nearly 0mm. The turbine is placed in between the upper hand and lower hand; this small displacement near both the hands may not affect the movement of the turbine.



8) Strain Analysis

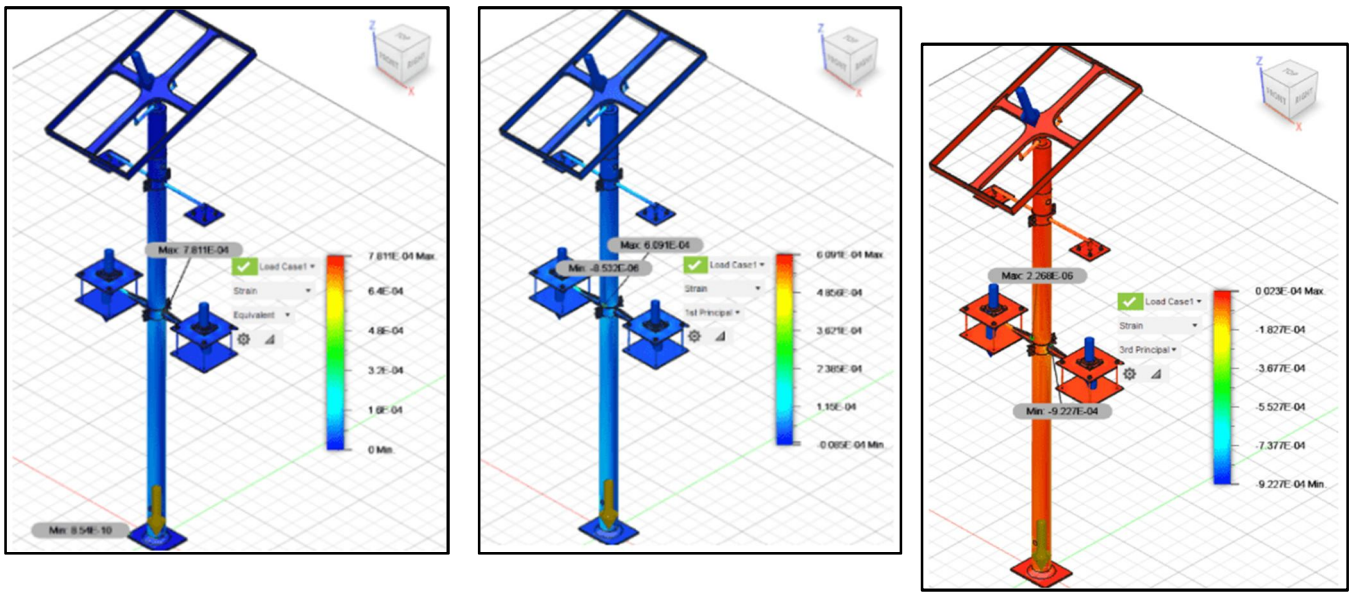


Fig 9: Strain analysis

With the given load conditions the design can withstand the load and the maximum strain that is observed in the design is 7.811 10-4 at the joint between lower hand and pole and the minimum strain occurred at the base plate of the pole.

Strain	Minimum	Maximum
Equivalent	8.54 10-10	7.811 10-4
1st Principal	-8.532 10-6	6.091 10-4
3rd Principal	-9.227 10-4	2.268 10-6
Normal XX	-6.037 10-4	5.631 10-4
Normal YY	-2.31510-4	2.372 10-4
Normal ZZ	-1.385 10-4	4.228 10-4
Shear XY	-5.487 10-4	3.985 10-4
Shear YZ	-2.76 10-4	1.416 10-4
Shear ZX	-2163 10-4	1.653 10-4

Table 4: Strain Analysis Data

B. ANSYS Analysis (CAE)

ANSYS is a powerful computational fluid dynamics (CFD) software that can be used to analyze the performance of wind turbines. In the case of a Savonius vertical axis wind turbine (VAWT), ANSYS can be used to simulate the airflow around the turbine blades and predict the power output of the turbine. For a two-blade or three-blade Savonius VAWT, ANSYS can be used to model the turbine geometry and simulate the airflow around the blades as they rotate. The software can analyze factors such as the angle of attack, the velocity of the wind, and the shape of the blades to predict the power output of the turbine.

To perform this analysis, we used ANSYS to create a 3D model of the wind turbine and its surrounding environment. We then applied a wind load to the blades at three different velocities - 7 m/s, 14 m/s, and 21 m/s - and calculated the resulting torque and power output. In this context of a wind turbine, torque refers to the rotational force that is generated by the blades as they turn in response to the wind. This torque is then used to drive the rotor and generate electrical power. The torque output of a wind turbine is dependent on a number of factors, including the wind speed, the blade design, the rotor diameter, and the generator efficiency. As the wind speed increases, the torque output of the turbine also increases, up to a certain point.

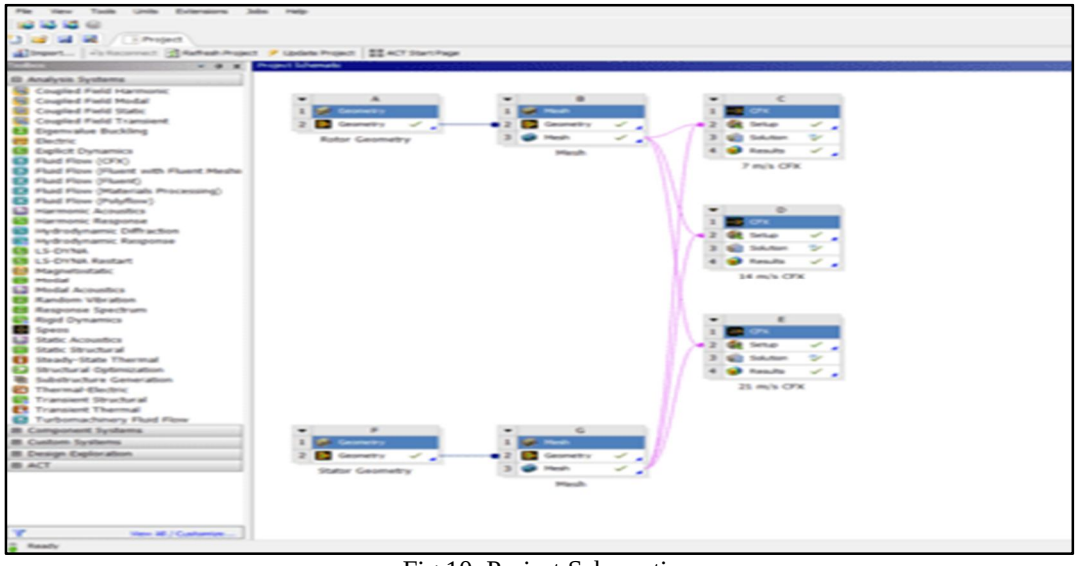


Fig 10: Project Schematic

1) Modeling the Turbine

The first step is to create a 3D model of the wind turbine in ANSYS. This involves creating a geometric representation of the turbine's blades, hub, and supporting structure. The model should be accurate and detailed enough to capture the important features of the turbine's geometry. This Process is done using Design modular in Ansys by considering the Dimensions which we used to create the CAD model .

a) Rotor Geometry

The rotor section comprises the rotating components of the turbine, including the blades, shaft, and a cylindrical casing. The entire geometry of the rotor section is designed using the Design Modeler window due to its 3D nature. To create the rotor blades, a Boolean subtraction operation is performed without preserving the body, and the material of the cylindrical casing is changed to fluid since it does not represent a physical body. This enables the rotor section to rotate freely inside the stator, creating the necessary fluid flow for energy generation.

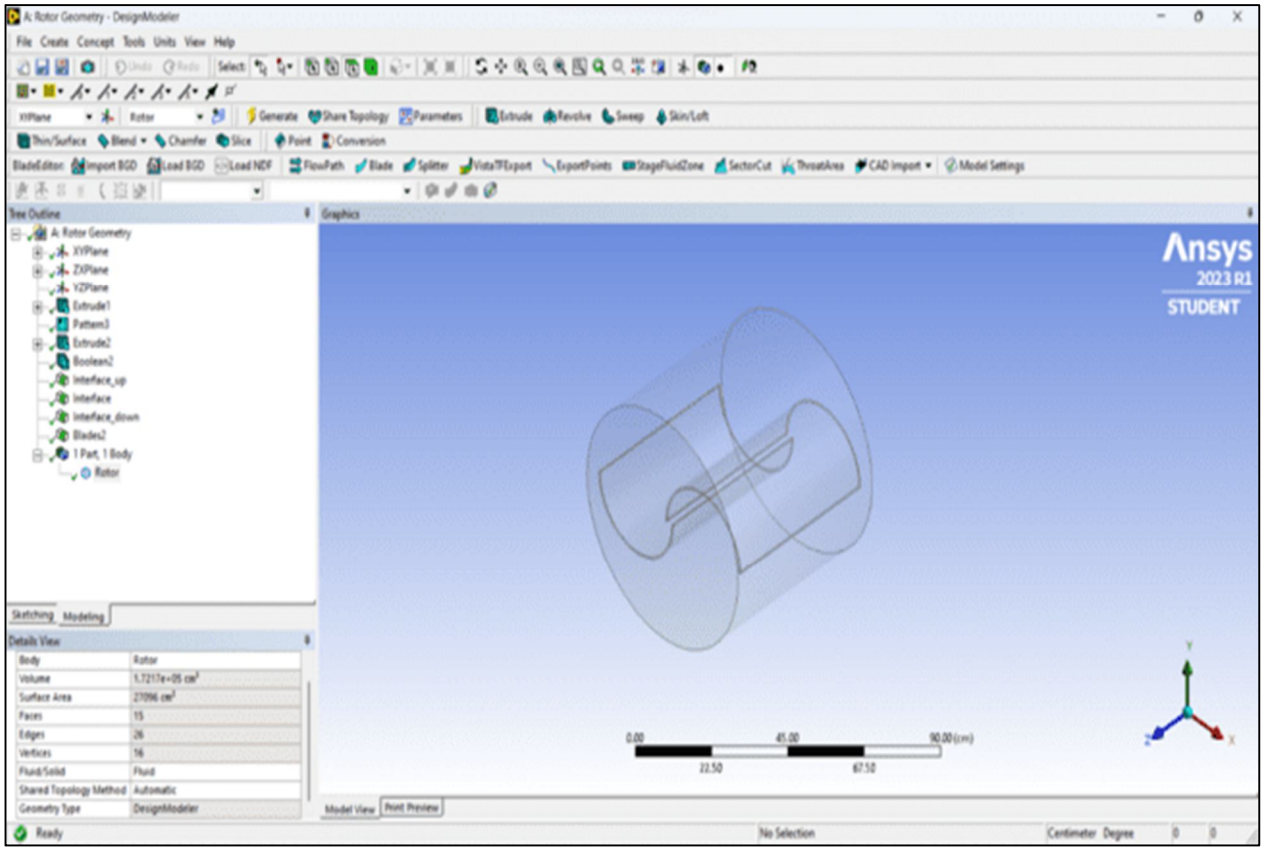


Fig 11: Rotor Geometry

Table 5: Rotor Dimensions

ROTOR DIMENSIONS	
Turbine Blade Diameter	40 cm
Turbine Blade Height	50 cm
Turbine Blade overlap Distance	5 cm
Enclosure Height	53cm
Enclosure Diameter	63 cm

b) Stator Geometry

The stator section is the stationary component of the system, where the simulations of the rotor take place. It serves as a casing or housing for the entire rotor part, with a large enough volume to enclose the rotor interface surface. The stator is a cuboid-shaped structure with a cylindrical cavity situated closer to the inlet end for accommodating the rotor section. The stator is entirely fluid and remains stationary while the rotor rotates inside it.

Once the Stator geometry is created in ANSYS, the user can define the material properties, boundary conditions, and other relevant parameters. ANSYS provides a range of analysis options, including structural analysis, thermal analysis, and electromagnetic analysis, that can be used to analyze the performance of the stator geometry and the overall system. Overall, accurately defining the stator geometry is essential for the accurate analysis of wind turbine using ANSYS. The dimensions of the stator, such as length and width, need to be carefully specified to ensure that the ANSYS model provides accurate results.

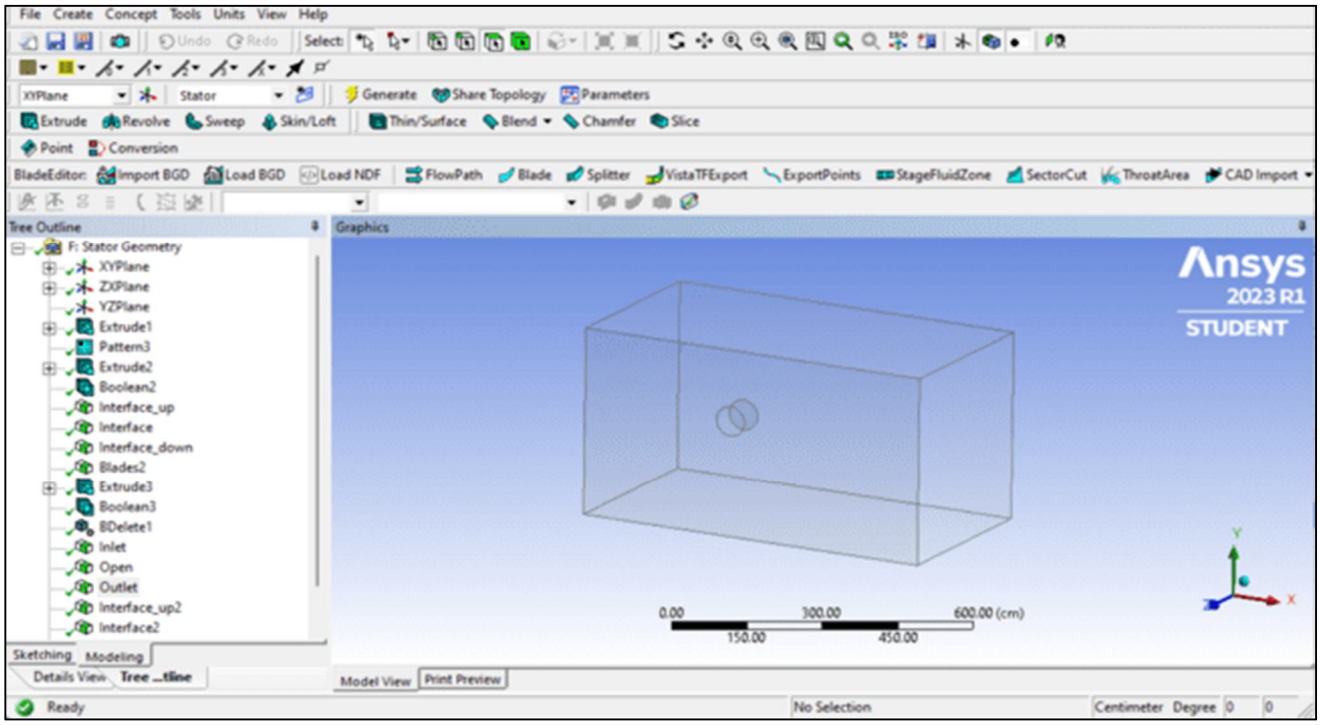


Fig 12: Stator Geometry

STATOR DIMENSIONS	
Stator Length	750 cm
Stator Width	400 cm
Stator Height	50 cm
Cavity Volume	1.1983e+08 cm^3

Table 6: Stator Dimensions

2) Meshing Process

To analyze fluid overflows, inflow disciplines are divided into smaller subdomains comprised of geometric shapes such as hexahedral and tetrahedral in 3D and quadrilaterals and triangles in 2D. The governing equations are discretized and solved within each of these subdomains using one of three methods - finite volumes, finite elements, or finite differences. These subdomains are commonly referred to as cells or elements, and the collection of all cells is known as a mesh or grid. To simulate the rotor part and stator corridor, ANSYS 2023 R1 Meshing stand-alone system is used to create multiple meshes, which are then combined for analysis. This approach of breaking down the analysis into smaller subdomains and solving the governing equations within each cell is known as computational fluid dynamics (CFD).

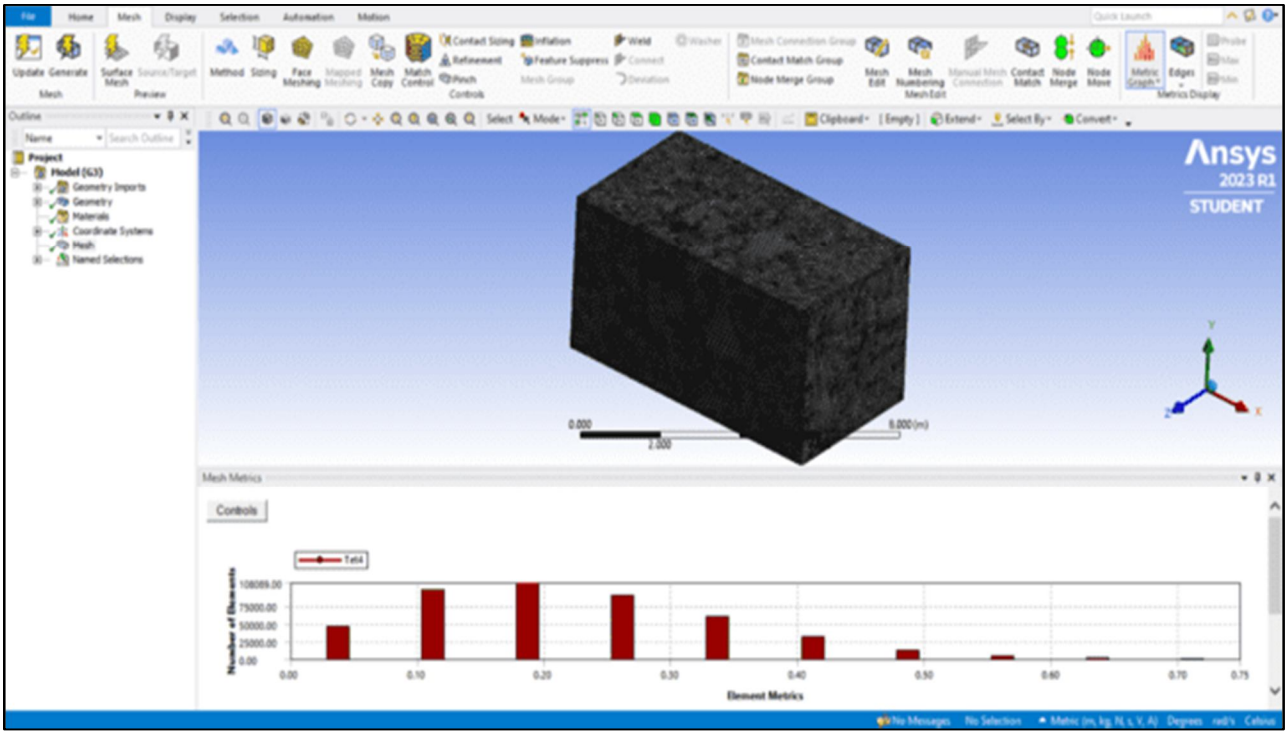


Fig 13: Mesh Data Report of Rotor

Details of "Mesh"

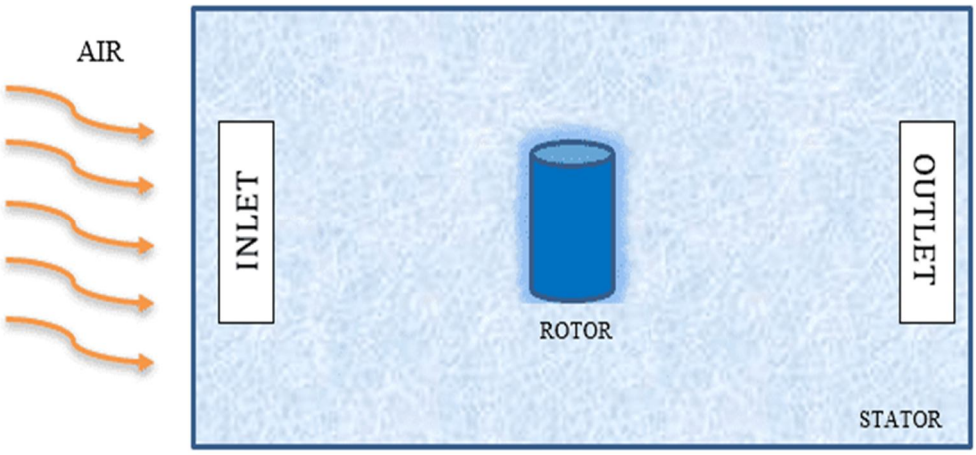
Display	
Display Style	Use Geometry Setting
Defaults	
Physics Preference	CFD
Solver Preference	CFX
Element Order	Linear
Element Size	Default
Sizing	
Use Adaptive Sizi...	Yes
Resolution	7
Mesh Defeaturing	Yes
Defeature Size	Default
Transition	Slow
Span Angle Center	Fine
Initial Size Seed	Assembly
Bounding Box Di...	9.3941 m
Average Surface ...	17.081 m^2
Minimum Edge L...	1.9792 m

Fig 14: Details of Mesh

3) Boundary Condition and Setup

Boundary conditions are a fundamental part of ANSYS analysis, as they determine how the model interacts with its external environment. In ANSYS, boundary conditions are used to define loads and constraints that affect the behavior of the model. Loads refer to forces, pressures, temperatures, or other inputs that are applied to the model, while constraints define fixed or restrained regions of the model.

The setup of an ANSYS analysis involves defining the model geometry, mesh, and solver options. The geometry refers to the physical dimensions and shape of the model, while the mesh defines the discretized representation of the model that the solver uses to calculate results. The solver options include settings such as the type of solver used, convergence criteria, and output options. Proper boundary conditions and setup are crucial for obtaining accurate and meaningful results in ANSYS analysis. They require careful consideration and selection based on the specific problem being analyzed. ANSYS provides a wide range of tools and resources to aid in this process, including tutorials, documentation, and support from the ANSYS community.



Boundary Condition Data	
Turbine Material	Aluminium
Fluid Type	Air
Analysis Carried Out From	Inlet
Temperature of Air	25°C
Inlet Type	Velocity
Inlet Velocities	7 m/s , 14 m/s , 21 m/s
Flow Regime	Subsonic
Viscosity	Laminar
Outlet Type	Pressure
Pressure	1 atm
Computed Values	Relative to Inlet

Table 7: Boundary Conditions

4) Ansys Solver Manager

The ANSYS Solver Manager is a powerful tool that can be utilized for analyzing the performance of two-blade and three-blade wind turbines. The tool offers various options for users to simulate the performance of the turbine under different operating conditions, such as different wind speeds and angles of attack. To use the ANSYS Solver Manager for a two-blade wind turbine, users can create a 3D model of the turbine in a CAD software and import it into ANSYS. Next, users can define the relevant material properties, boundary conditions, and other parameters in ANSYS. Once the model is set up, the Solver Manager can be used to run simulations to analyze the performance of the turbine. Users can specify the solver settings, such as convergence criteria and time steps, and monitor the progress of the simulation.

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a) 2-Blade Turbine Solution

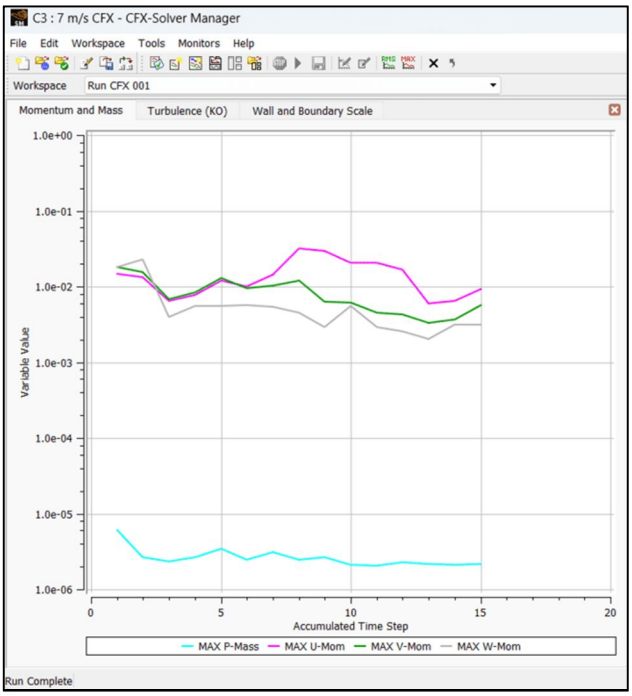


Fig 15: 2-blade ,7m/s Graph

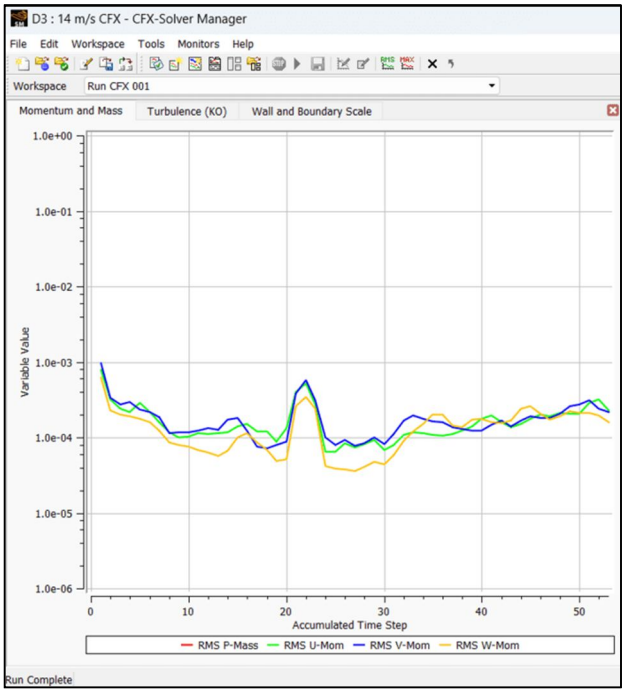


Fig 16: 2-blade ,14m/s Graph

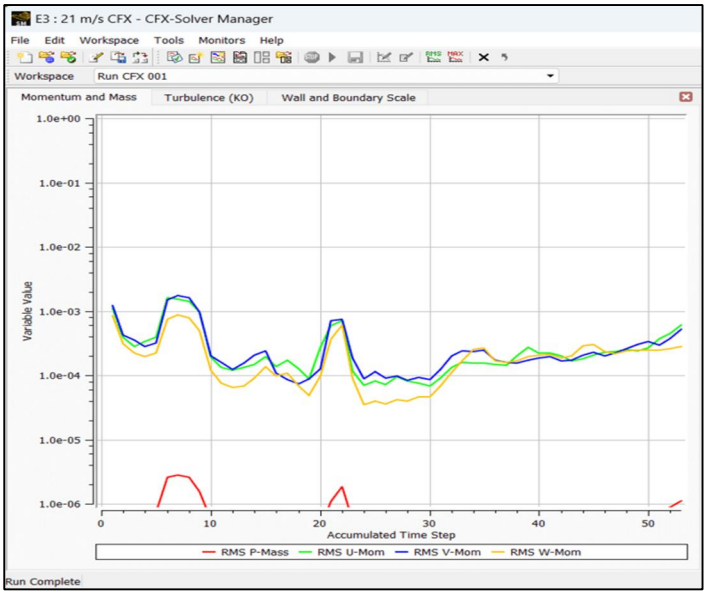


Fig 17: 2-blade ,21m/s Graph

In conclusion, the ANSYS Solver Manager is a powerful tool that can be used to simulate and analyze the performance of two-blade and three-blade wind turbines. The tool provides a range of options for analyzing the performance of the turbine, allowing users to evaluate the performance of the turbine under different operating conditions. To use the ANSYS Solver Manager for three-blade wind turbines, users need to create a 3D model of the turbine in a CAD software, and import it into ANSYS. Next, users need to define the relevant material properties, boundary conditions, and other parameters in ANSYS, such as the wind speed and angle of attack. Once the model is set up, the Solver Manager can be used to run simulations to analyze the performance of the turbine.

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b) 3-Blade Turbine Solution

c)

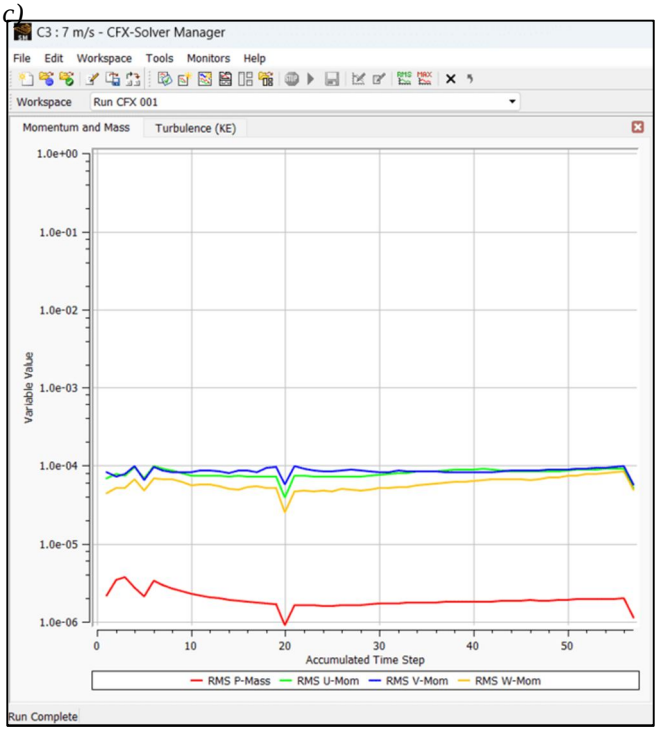


Fig 18: 3-blade ,7m/s Graph

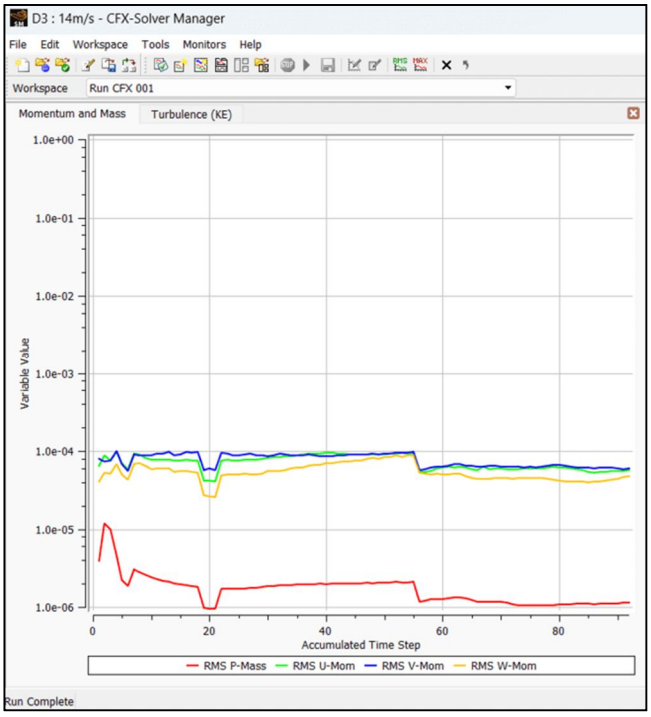


Fig 19: 3-blade ,14m/s Graph

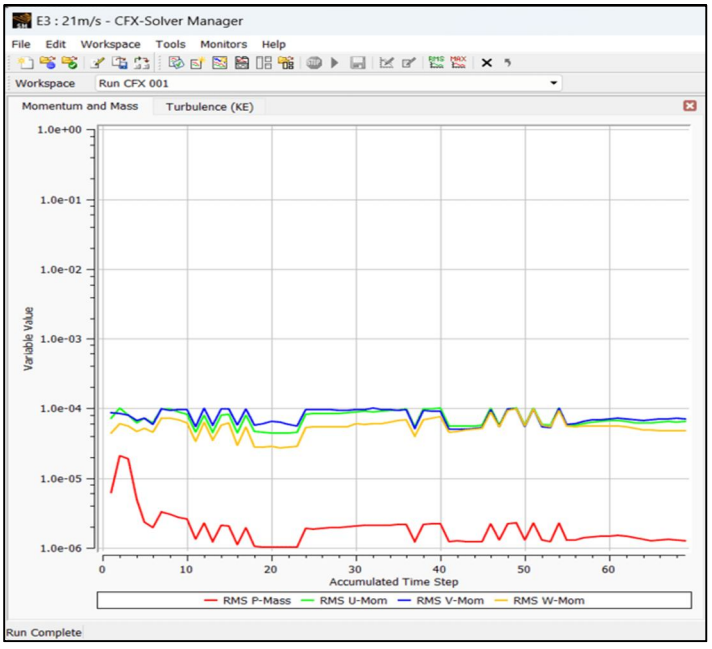


Fig 20: 2-blade ,21m/s Graph

5) Analysis and Results

Our analysis aims to investigate the characteristic properties and behavior of our 2-Blade and 3-Blade Savonius Wind Turbine in different atmospheric conditions. To achieve this, we subjected the turbine blade model to various wind velocities and angular velocities. Our experimental setup involved testing the turbine at different wind speeds and their corresponding angular velocities.

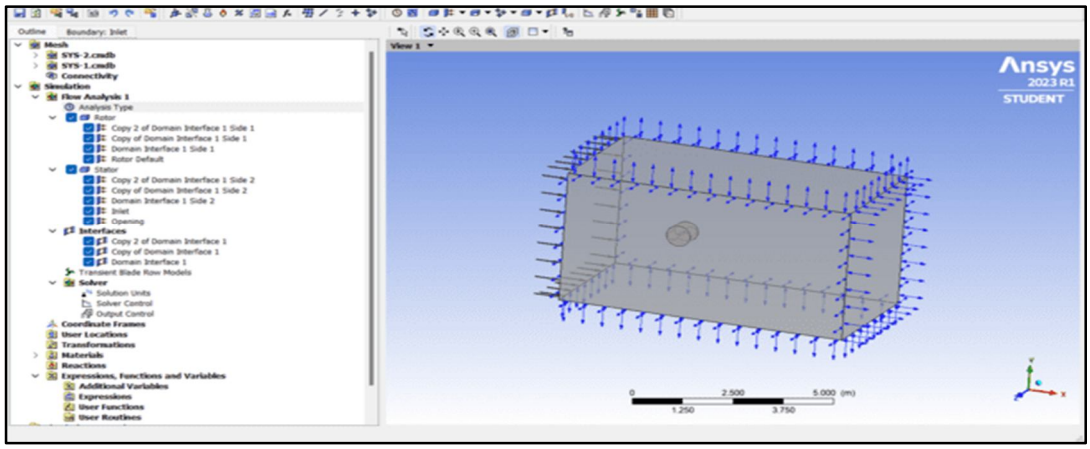
During the simulation, the ANSYS Solver Manager tracks the performance of wind turbine, such as the Angular velocities of the turbine, the torque generated, and the power output. The simulation provides information on the airflow and pressure distribution around the blades, which can be used to optimize the design of the blades for maximum power generation.

Overall, the ANSYS Solver Manager provides a powerful tool for simulating and analyzing the performance of three-blade wind turbines. The CFD analysis enables users to model the interaction of the blades with the surrounding air, providing valuable insights into the performance of the turbine.

DATA ANALYSIS ON SAVONIUS WIND TURBINE		
Turbine Type	Angular Velocity	Wind Speed (m/s)
2-Blade	0.9 rad/s	7
		14
		21
3-Blade	0.9 rad/s	7
		14
		21

Table 8: Data Analysis

Shown below is the preset analysis environment data for CFX using ANSYS 2023 R1



d) 2-Blade Turbine Results

The ANSYS CFX pre-window is configured with cartesian velocity components to replicate the wind speed for both the stator and rotor. In addition, under the same setup condition, the motion of the rotor domain is set to 0.9 rad/s to simulate the desired blade rotation speed and direction.

- *7 m/s wind Speed*

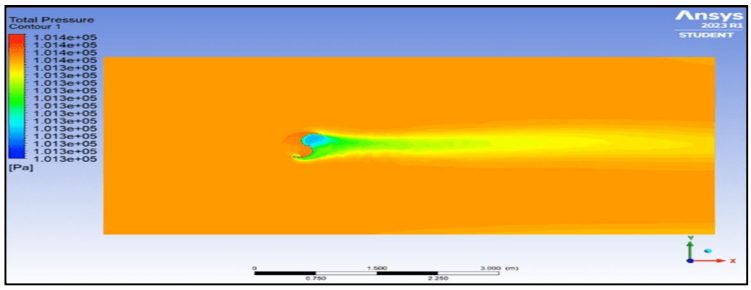
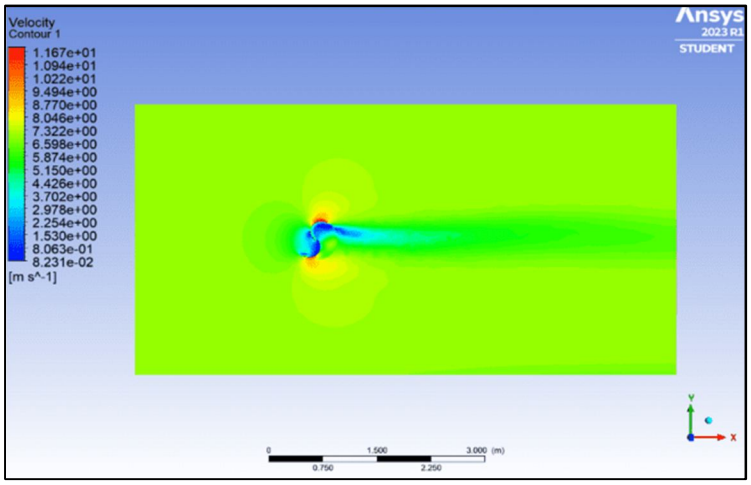


Fig 21: Total Pressure contour at IsoSurface

Max Pressure	1.014e+05 Pa
Min Pressure	1.013e+05 Pa
Velocity	7m/s
Angular Velocity	0.9 rad/s

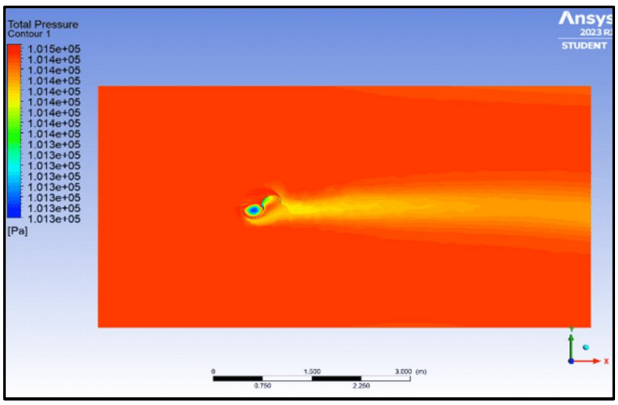


Max Velocity	1.167e+01 m/s
Min Velocity	8.231e-02 m/s
Velocity	7 m/s
Angular Velocity	0.9 rad/s

Fig 22: Velocity contour at IsoSurface

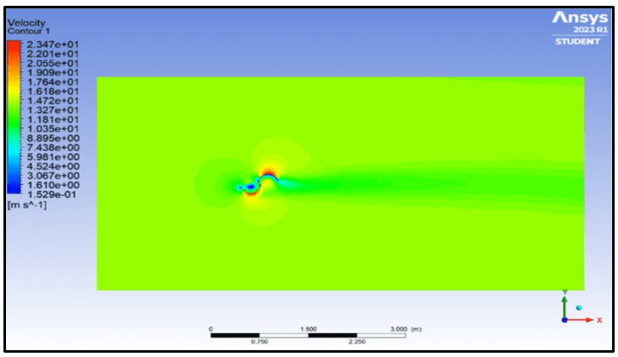
RESULTS (7m/s)	
Force	9.417 N
Torque	67.5719 Nm
Volume on Rotor	0.172146 m^3
Power	60.814 W

- *14 m/s Wind Speed*



Max Pressure	1.0151e+05 Pa
Mi Pressure	1.0131e+05 Pa
Velocity	14m/s
Angular Velocity	0.9 rad/s

Fig 23: Total Pressure contour at IsoSurface

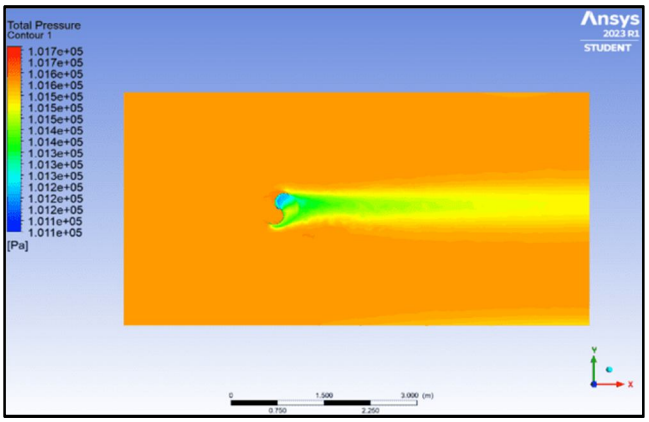


Max Velocity	2.347e+01 m/s
Min Velocity	1.529e-01 m/s
Velocity	14 m/s
Angular Velocity	0.9 rad/s

Fig 24: Velocity contour at IsoSurface

RESULTS (14 m/s)	
Force	23.7842 N
Torque	68.4432 Nm
Volume on Rotor	0.172146 m^3
Power	63.798 W

- *21 m/s wind Speed*



Max Pressure	1.0171e+05 Pa
Min Pressure	1.0111e+05 Pa
Velocity	21m/s
Angular Velocity	0.9 rad/s

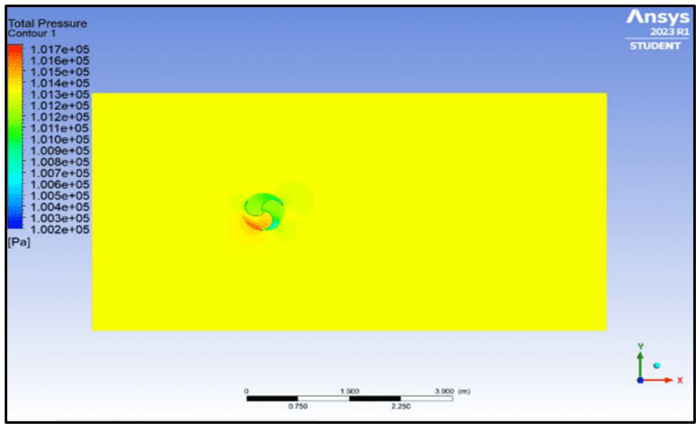
Fig 25: Total Pressure contour at IsoSurface

RESULTS (21 m/s)	
Force	83.6372 N
Torque	79.5917 Nm
Power	71.63 W

e) 3-Blade Turbine Results

The ANSYS CFX pre-window is configured with cartesian velocity components to replicate the wind speed for both the stator and rotor. In addition, under the same setup condition, the motion of the rotor domain is set to 0.9 rad/s to simulate the desired blade rotation speed and direction.

- *7 m/s wind Speed*



Max Pressure	1.017e+05 Pa
Min Pressure	1.002e+05 Pa
Velocity	7 m/s
Angular Velocity	0.9 rad/s

Fig 26: Total Pressure contour at IsoSurface

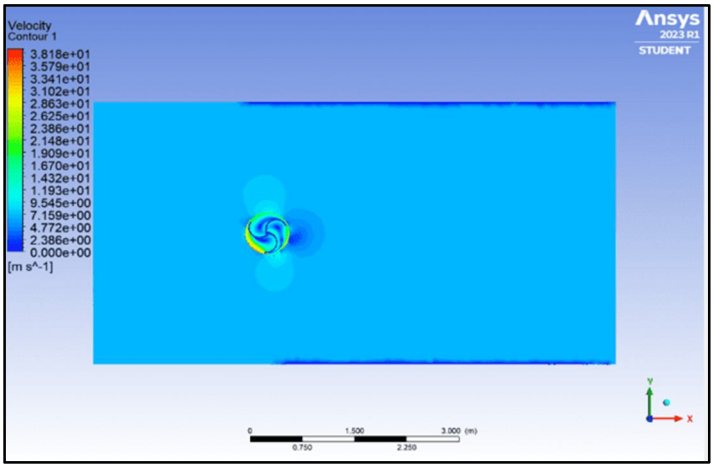


Fig 27: Velocity contour at IsoSurface

Max Velocity	3.818e+01 m/s
Min Velocity	0.000e+00 m/s
Velocity	7 m/s
Angular Velocity	0.9 rad/s

RESULTS (7m/s)	
Force	63.7829 N
Torque	41.9675 Nm
Volume on Rotor	0.183414 m^3
Power	37.770 W

- *14 m/s wind speed :*

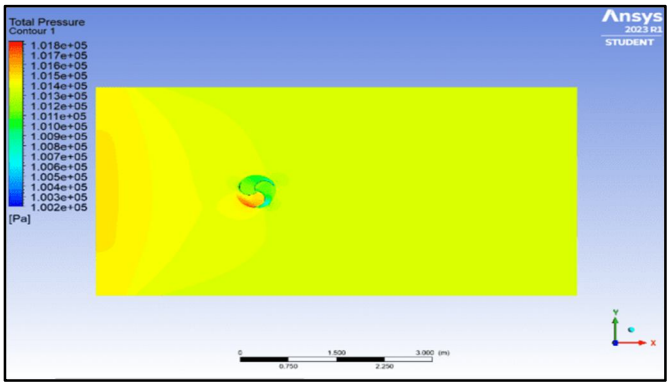


Fig 28: Total Pressure contour at IsoSurface

Max Pressure	1.018e+05 Pa
Min Pressure	1.002e+05 Pa
Velocity	14 m/s
Angular Velocity	0.9 rad/s

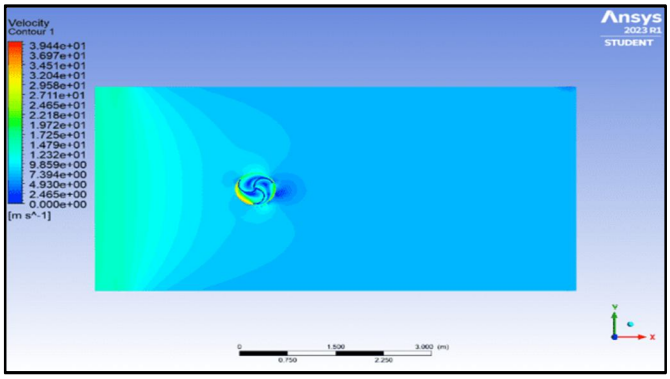
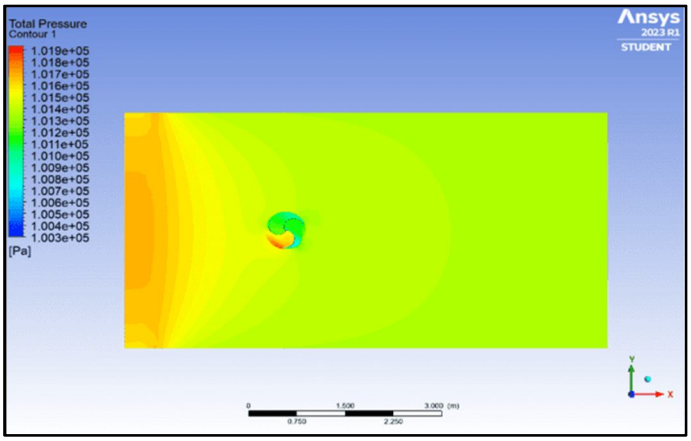


Fig 29: Velocity contour at IsoSurface

Max Velocity	3.944e+01 m/s
Min Velocity	0.000e+00 m/s
Velocity	14 m/s
Angular Velocity	0.9 rad/s

RESULTS (14 m/s)	
Force	74.1635 N
Torque	43.3486 Nm
Volume on Rotor	0.183414 m^3
Power	39.013 W

- *21 m/s wind speed :*



Max Pressure	1.019e+05 Pa
Min Pressure	1.003e+05 Pa
Velocity	21 m/s
Angular Velocity	0.9 rad/s

Fig 30: Total Pressure contour at IsoSurface

RESULTS (21 m/s)	
Force	89.5698 N
Torque	44.8803 Nm
Power	40.392 W

VIII. CONCLUSION

In conclusion, hybrid power systems have become an increasingly popular solution for generating power from multiple sources. With the advancement of technology, computer-aided design (CAD) in fusion has enabled engineers to design more efficient and effective hybrid systems. Furthermore, static stress simulation has played a critical role in ensuring the structural integrity of these systems under various operating conditions.

ANSYS simulation work has also been instrumental in evaluating the performance of hybrid power systems. By simulating various scenarios, engineers can identify potential issues and optimize the system design to improve performance and efficiency. Through these simulations, engineers can also better understand the behavior of hybrid power systems under different operating conditions, allowing for more informed decision-making.

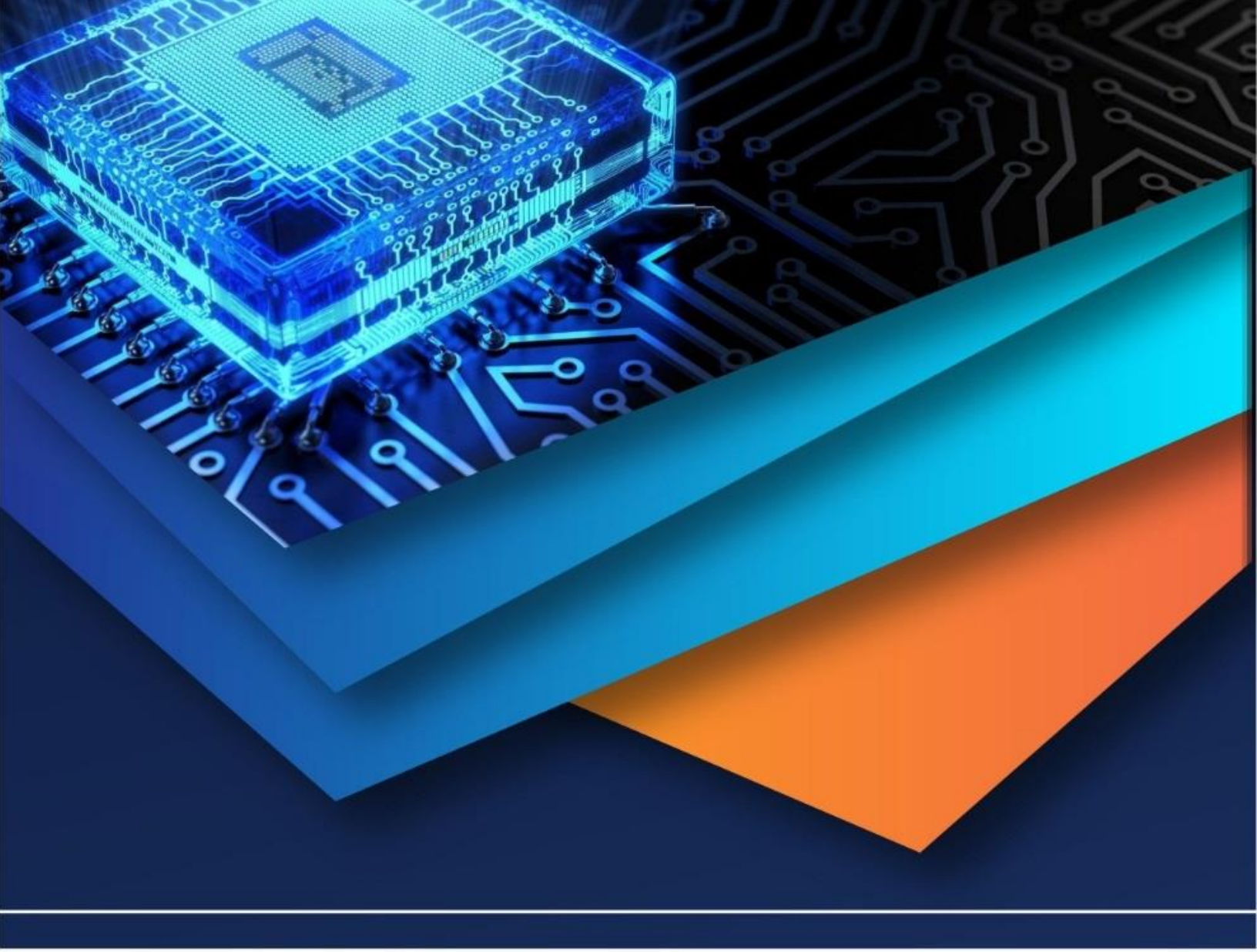
Overall, the integration of CAD in fusion 360, static stress simulation, and ANSYS Analysis work has been essential in the design and optimization of hybrid power systems. The results from these tools have shown that hybrid power systems can provide reliable and sustainable sources of energy, which is crucial for meeting the growing energy demands of our society. With further advancements in technology and ongoing research, it is expected that hybrid power systems will continue to play an increasingly significant role in our energy landscape.

The average Power output of a Monocrystalline Solar panel is around 260-280W. From our research the average power output from a 2-Blade VAWT turbine is 60-80W for a hypothetical wind velocity of range 7m/s to 21m/s .In our model we are using two turbines ,so the net power output will be double i.e,120-160 W. But in a normal day condition the wind velocities might be higher than this value ,so the net power output from the wind turbine will always be >120W.Hence the Hybrid Power System combining both Solar panel and Wind turbine will nearly produce a minimum power of 380 W.

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