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ELECTRICAL AND MECHNICAL ENGINEERING

ENERGY HARVESTING SYSTEM FOR HIGHWAYS AND RAILWAY TRACKS

A PROJECT REPORT

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We praise and thank Allah SWT for His greatness and for giving us the intelligence and courage to complete this research. Our work displays a respect for Allah's strength, intelligence, and goodness. We thank Allah and ask for His blessings for direction and success before beginning any endeavor. This paper and the research behind it would have not been possible without the exceptional support of our supervisor, Dr. Abdur Rehman Mazhar. His knowledge, enthusiasm and attention to detail have been an inspiration and has helped us in keeping our work on track. We would also like to acknowledge the support of the faculty Mechanical Department for guiding us where we needed direction and the staff for their help. We are deeply indebted to our families for their love and support. Thank you all for the strength you gave us. They motivated, assisted, and enabled us to do the best we could on this project. Last, but not the least, we would like to extend our gratitude to our colleagues for their continuous support and presence wherever needed the courage to complete this research. This endeavor would not have been possible without Danial Maqbool and his constant efforts to motivate us. We could always count on his feedback and moral support.

ABSTRACT

The energy consumption in the world is increasing exponentially causing the depletion of fossil fuel-based resources. At the same time, there is extreme volatility in their prices and supply. Consequently, we must adapt the most energy efficient practices to harness energy to its maximum potential. At the same time, the global debate on greenhouse gas emission is intensifying. At the recent COP-27, scientists put forward the fact that if greenhouse gas emissions are not minimized the earth will reach a point of no return. This will cause permanent increments in global temperatures and have a catastrophic impact on the planet and its ecosystem.

For these reasons, the world must move towards environmentally friendly power that is also economical. Solar and wind energy are viable sources of renewable energy that must be harnessed to their maximum potential. In this project a kinetic energy harvesting system that converts solar and wind energy into electrical energy is presented. The energy is then stored in a battery. The framework gives a proficient way to control and check energy generation and storage. The fabrication of a vertical axis wind turbine to demonstrate and highlight the potential of renewable energy as an applicable power source is highlighted in the project. This device can be used for micro-power generation at domestic levels to maximize its impact in numerous applications.

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NOMENCLATURE AND ABBREVIATIONS

VAWT	Vertical axis wind turbine
HAWT	Horizontal axis wind turbine
PV	Photovoltaic
RPM	Revolutions per minute
V_{rotor}	Speed of Turbine rotor
V	Speed of wind
R	Radius of rotor
ω	Angular velocity of rotor
ρ	Density of air
A	Swept area of rotor
T	Actual torque develops by rotor
T_w	Theoretical torque
P_A	Total power available from wind
P_T	Max Power obtained from wind
TSR	Tip speed ratio

Chapter 1: Introduction

1.1 Background

Several technologies targeted at capturing clean and sustainable energy have been developed because of the rising need for renewable energy sources. Among these technologies, solar and wind energy have drawn a lot of interest because of their availability and favorable environmental effects. However, there are drawbacks to both solar and wind energy, including its intermittent nature and reliance on the weather. Hybrid solar wind power generation has become a desirable choice as a potential means of overcoming these constraints and improving the dependability and efficiency of renewable energy systems.

Photovoltaic (PV) panels are used to convert sunlight into electricity to provide solar energy. The production of solar energy has a number of benefits, including global availability, scalability, and minimum environmental effect. However, the generation of solar energy is intermittent because of factors like cloud cover and the time of day. Wind turbines, on the other hand, are used to capture wind energy and turn the kinetic energy of the wind into electrical energy. Benefits of a resource that is comparatively constant for wind power generation.

1.2 Objective

This project's goal is to create and implement a hybrid solar-wind power generating system that is particularly made to be installed on highways and railway lines. The system intends to efficiently absorb and use renewable energy by taking advantage of the enhanced wind resource that is made accessible in these areas because of the movement of cars and trains. The main goal of the project is to combine the complementary qualities of solar and wind energy sources by integrating solar panels with a vertical axis windmill of the Savonius type. An effective energy storage mechanism will be incorporated into the system to hold extra energy during times of high production and provide it during periods of low generation or higher demand. Real-time monitoring sensors will also be used to collect information on temperature, humidity, battery voltages and wind speed. The project aims to demonstrate the viability, effectiveness, and economic viability of hybrid solar and wind power generation in highway and railway environments, assisting in the production of sustainable energy and lowering carbon emissions in the transportation sector.

1.3 Energy Harvesting

Energy harvesting is the technique of capturing and then using energy from unmanaged environmental sources. It entails transforming readily accessible natural energy, such as light, heat, vibration, or movement, into useful electrical energy. With this strategy, electricity may be produced without the need of conventional energy sources like batteries or the electrical grid.

1.3.1 Significance of energy harvesting

Harvesting of energy makes use of the environment's plentiful renewable energy sources, such sunshine, wind, vibrations, and prevailing heat. Utilizing these sources helps create a greener, more sustainable energy ecosystem and lessens dependency on fossil fuels. It enables the effective use of energy that would otherwise be lost in the environment. It makes it possible to convert natural resources into useful electrical power, lowering energy waste and raising total energy efficiency. Applications in distant or remote regions, where conventional power sources are not easily accessible, might benefit greatly from energy harvesting. It makes it possible to build autonomous systems that work without the constant requirement for external power sources or battery refills. Simple energy collecting devices have a long operating lifespan and need very little maintenance once installed. This lowers the ongoing expenses of power supply and maintenance, making it a long-term cost-effective alternative. Numerous industries, such as wireless sensor networks, wearable electronics, monitoring systems, IoT gadgets and many more, use energy harvesting. It makes it possible for these gadgets to function effectively and constantly without requiring regular battery changes or cable connections.

1.4 Scope

The project's scope includes the installation of a hybrid solar and wind power production system on highways and railway tracks. The project's goal is to use solar energy in addition to the plentiful wind resource that is present in these areas owing to the movement of cars and trains. The design, development, and installation of an integrated system that combines solar panels with a vertical axis windmill of the Savonius type are all included in the system's scope. It also entails the integration of power management circuits, real-time monitoring sensors, and energy storage devices. With the intention of demonstrating the system's potential for sustainable energy generation and assisting in the reduction of carbon emissions in the transportation sector, the project will assess the system's sustainability, efficiency, and economic viability.

1.5 Motivation

The growing need for sustainable and clean energy solutions throughout the world is what inspired this idea. Alternative energy sources must be investigated since conventional energy sources exacerbate climate change and environmental deterioration. This project intends to maximize the potential of hybrid solar wind power generation by utilizing the wind resource produced by cars and trains on roads and railway lines, in addition to solar energy. Inspiration originates from the requirement to create inventive and effective systems that can make use of the energy present in these situations. The implementation of such a system might improve energy security, lower carbon emissions, and advance sustainable development. The project also aims to show that this technology is feasible and economically viable, promoting its implementation in transport infrastructure to develop a greener and more sustainable energy environment.

Chapter 2: Literature Review

2.1 Overview

A viable approach for achieving sustainable and effective energy production is the fusion of solar and wind energy sources in hybrid solar wind power generation systems. The overview creates foundations for further investigation in this area by providing a thorough grasp of the concepts, advantages, problems, and research advancements in hybrid systems. To maximize energy production and raise system dependability, hybrid solar wind power generating systems combine the benefits of both solar panels and wind turbines. These systems can increase total energy output and lessen reliance on a single energy source by using the complementary nature of solar and wind resources.

Advantages of hybrid energy storage systems consist of a greater capacity for energy generation, enhanced system performance, and a lesser reliance on non-renewable energy sources. These systems provide the chance to maximize power output throughout various time periods and weather conditions by integrating solar and wind technologies, improving energy dependability and cost effectiveness.

There are some struggles for execution of hybrid energy production systems. Significant challenges include the variability and erratic nature of solar and wind resources, the complexity of system integration, and the requirement for efficient energy storage and management systems. To maximize the performance of hybrid systems and realize their full potential, these issues must be resolved.

The development of hybrid solar-wind power generating has been the subject of several research investigations and initiatives. These investigations concentrated on a variety of topics, such as system design, optimization strategies, control algorithms, and performance assessments. The gathered information and developments from these research projects have helped hybrid systems to continue to evolve and be improved.

2.2 Wind Energy Harvesting

Wind is the energy source that has grown the quickest worldwide since 1990, with a typical yearly increase of more than 26%. The research of the European Wind Energy Association draws the conclusion that integrating the desired wind power generation capacity of 300

GW by 2030—corresponding to an estimated integration level of up to 20%—is completely achievable based on data from studies and operational experiences. The technique of capturing the energy present in the flowing air and turning it into useful electrical energy is known as wind energy harvesting. It includes utilizing the wind's natural ability to produce energy. Wind turbines are specialized machines that absorb and transform the kinetic energy of the wind into electricity to harness its power. To maximize energy output, these turbines are carefully positioned in regions with strong, reliable winds. Wind energy is then converted into useable electrical energy that may be used to satisfy a variety of energy demands using several techniques and technologies. To reduce greenhouse gas emissions and reliance on fossil fuels, wind energy harvesting offers a renewable and sustainable form of electricity generation. To satisfy more sophisticated criteria for energy generation, contemporary wind farms are anticipated to include reliable power management algorithms. In a contemporary wind energy conversion system, a rotor with blades, an electric generator, an electric power converting device, and a transformer are the most frequently used device components for converting wind energy to electrical power. Figure 1 illustrates these components.

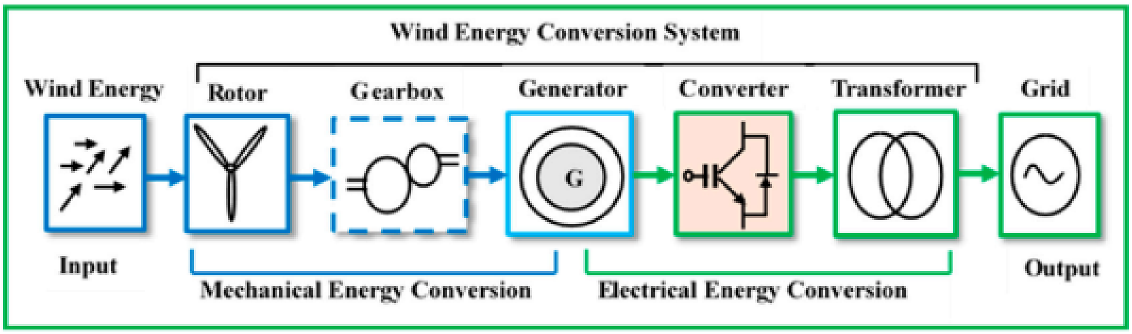

Figure 1 Wind energy conversion system

2.3 Wind Turbines and their types

Specialized devices called wind turbines are made to capture the kinetic energy of the wind and transform it into useful electrical energy. They are made up of several vital elements that combine to collect and convert wind energy.

The rotor, which has two or more blades, is a major part of a wind turbine. The rotor blades are often constructed from strong, lightweight materials like carbon fiber or fiberglass, and they are aerodynamically shaped to effectively absorb wind energy. The rest of the turbine receives the rotating motion through a connection between the rotor and a hub in the middle. Based on the direction of their rotor axis, wind turbines may be divided into two basic types: horizontal axis wind turbines (HAWTs) and vertical axis wind turbines (VAWTs). Figure 2 illustrating shapes of typical vertical and horizontal axis wind turbines.

Figure 2 Typical Horizontal (left) and vertical axis turbines (right)

2.3.1 Horizontal axis wind turbines (HAWTs)

The most prevalent kind of wind turbines are HAWTs. The rotor blades of this design are fastened to a horizontal shaft that is positioned perpendicular to the wind. The rotor blades revolve around the horizontal axis when the wind blows. The mechanical energy is transformed into electrical energy by this rotation, which powers a generator at the top of the turbine tower. Large-scale wind farms frequently employ HAWTs due to their high production and efficiency. Due to its design, which enables it to collect energy during the whole rotation of the blades when put under constant wind flow, HAWT are effective at capturing energy from wind force. The efficiency of horizontal axis wind turbines increases with the increase in the number of blades. Das, Apurb, et al in 2017 tested and gave the percentage efficiency of HAWTs with respect to number of blades.

2.3.2 Vertical axis wind turbines (VAWTs)

The blades may revolve along a vertical axis since VAWTs have a vertical rotor axis. The rotor blades can have a variety of shapes, including helical, Darrieus, and Savonius designs. The ability to capture wind from any direction makes VAWTs advantageous for sites with erratic or shifting wind patterns. They are suited for urban and residential applications because of their compact form and ability to be deployed at lower heights. In 2018 Ehab Hussein Bani-Hani et al. worked on feasibility of vertical axis wind turbines at highways, the results showed that because of moving vehicles at highways more energy can be produced. Figure 3 shows the schematic for highways wind turbine.

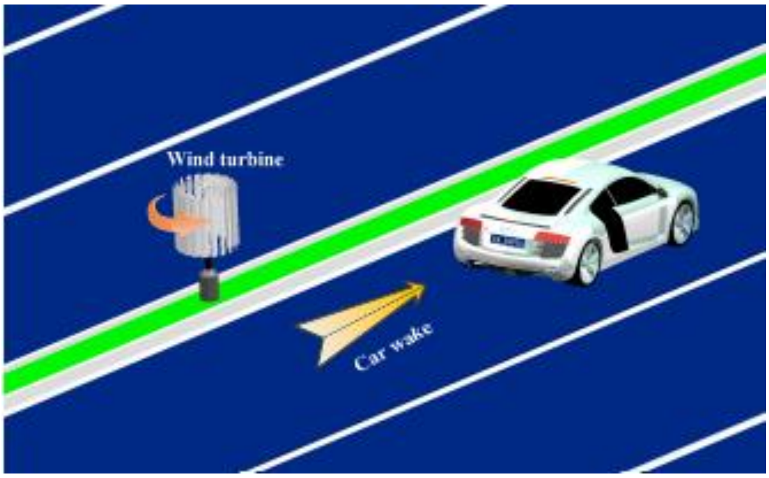

Figure 3 Highway wind turbine

2.3.3 Comparison

Consider their individual advantages and benefits when contrasting HAWTs with VAWTs. While VAWTs have certain benefits that make them useful for some applications, HAWTs are well-known for their greater efficiency and higher power output.

As VAWTs possess a vertical rotor axis, they can capture wind from all sides. Due to their adaptability, they are best suited for environments with erratic or shifting wind patterns. HAWTs, on the other hand, need to be pointed in the direction of the predominant wind to work at their best. VAWTs are useful for locations where wind direction may vary dramatically since they can catch wind from any direction, increasing their versatility.

Additionally, VAWTs may be deployed at lower heights and have a compact form. They are therefore ideal for confined urban or residential applications. In comparison to HAWTs, which require taller towers to capture larger wind speeds at greater heights, their smaller size and reduced height requirements also make installation and maintenance easier.

VAWTs are frequently thought of as having more aesthetically pleasant visual effects. Compared to the larger and more obvious HAWTs, they are less noticeable due to their distinctive shape and smaller size. When installing wind turbines near people or in regions where visual impact is an issue, this can be useful.
In addition, VAWTs often make less noise than HAWTs do. They are more suited for noise-sensitive locations such residential areas because of their small size and slower spinning rates, which help to minimize noise levels.

Although VAWTs may not be as efficient or produce as much power as HAWTs, their ability to adapt to a variety of wind conditions, smaller size, appealing appearance, and low noise level make them a desirable option for some applications. Depending on the project's unique needs, site circumstances, available space, and local laws, VAWTs or HAWTs may be used. Given its advantages, VAWTs may be a good option for urban or residential buildings where space, aesthetics, and noise are crucial factors.

2.4 Types of VAWTs

The Savonius and Darrieus turbines are the two primary varieties of vertical axis wind turbines (VAWTs).

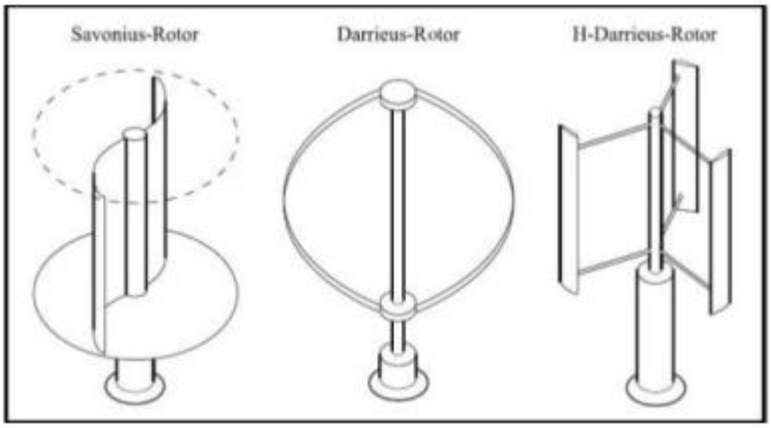

Figure 4 Main types of VAWTs [14]

2.4.1 Savonius Type VAWTs

Savonius turbines feature a straightforward and reliable design that consists of two or three blades with a scooped form that are vertically orientated. The wind passes through the curved blades and produces a drag force that turns the turbine. Savonius VAWTs are appropriate for locations with moderate wind conditions since they can start and run at low wind speeds. They have a reputation for capturing wind from all angles, making them flexible to changing wind patterns. Due to its simplicity and affordability, Savonius turbines are frequently utilized in small-scale applications and experimental projects

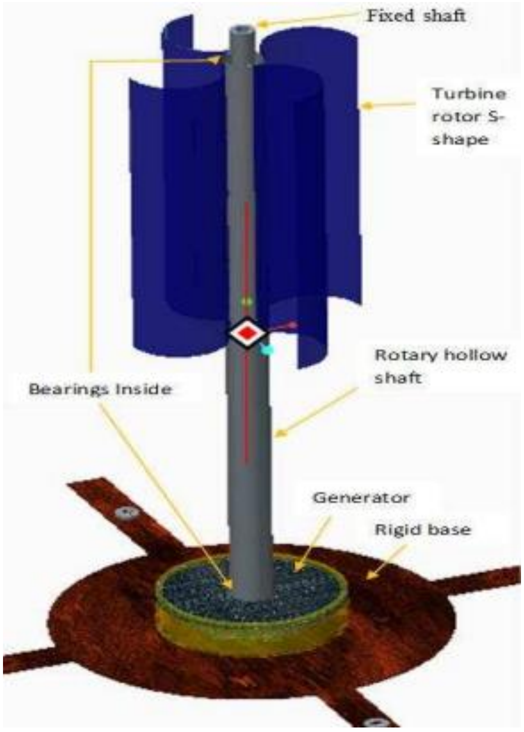

Figure 5 Savonius type VAWT [19]

2.4.2 Darrieus Type VAWTs

Darrieus turbines have vertically positioned curved blades that resemble an eggbeater or an aircraft propeller. These blades are affixed to a central shaft, and when the wind blows over them, lift forces are generated, spinning the turbine. Darrieus VAWTs have the ability to self-start, which enables them to start spinning without a source of power from the outside. They are widely known for their high efficiency and can operate effectively in winds of varying intensities. However, they are prone to turbulence and instability, and they may have issues in mild breezes. Darrieus turbines are often used several wind energy applications.

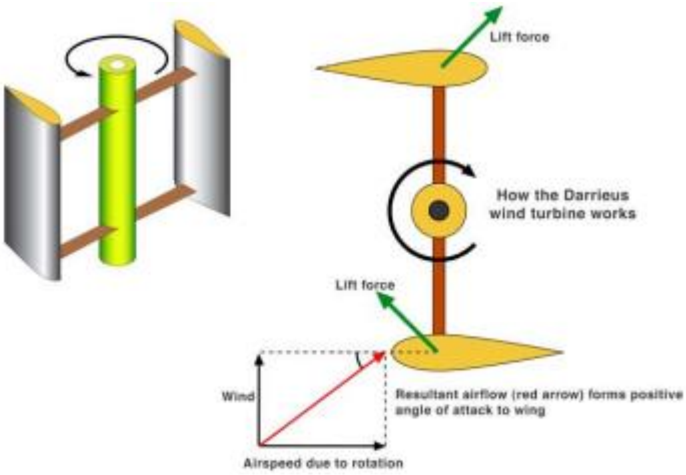

Figure 6 Darrieus type VAWT [20]

2.4.3 Comparison

There are several advantages and disadvantages of savonius and darrieus type wind turbines and we should consider their comparison for best selection from them for our application.

The simple and dependable savonius VAWT design comprises of scooped-shaped blades that spin about a shaft at the center of it. They work effectively in wind conditions with little or no wind, which makes them perfect for areas with modest wind resources. Savonius turbines can operate in a variety of wind conditions thanks to their unique shape, which enables them to catch wind from all directions. This adaptability is especially helpful in areas where wind patterns change often.

Savonius turbines are also well suited for low-speed applications because to their strong torque output. Their usage in different small-scale power production projects, such as isolated off-grid regions or private residential applications, is made possible by this quality. Additionally, their solid design increases their endurance and resilience to bad weather.

While Savonius VAWTs have these advantages, it's crucial to remember that they often perform less efficiently than Darrieus turbines. In moderate to strong winds, Darrieus VAWTs are renowned for their better power production and efficiency. They are less suited to regions with low wind speeds because to their complicated construction and reliance on lift forces for rotation.

2.5 Blade types of Savonius VAWTs

There are four blade types of savonius type vertical axis wind turbines.

2.5.1 Curved

Curved blades have a curved form. With this design, lift forces are produced when the wind passes over the turbine's blades, enhancing its aerodynamic performance. In higher wind speeds, curved blades can improve the turbine's overall efficiency and energy production capabilities.

2.5.2 Straight

Straight blades have flat shapes from origin to tip. They frequently appear in smaller-scale turbines because of their straightforward design. Straight blades are a practical solution for several applications since they are reasonably simple to produce and maintain.

2.5.3 Aerofoil

Savonius VAWT aerofoil blades are shaped similarly to conventional airfoils seen on wings of aircraft. The turbine performs better in terms of power production and efficiency because to the curved shape, which helps create lift forces. To maximize the amount of wind energy captured, Savonius VAWTs on a bigger scale frequently include aerofoil blades.

2.5.4 Twisted

Twisted blades have a twist that runs the length of the blade. The twist accounts for the varied wind speeds throughout the blade's length and enables optimum performance over the whole span of the blade. By increasing the turbine's total efficiency through design optimization, more power may be generated.

2.5.5 Comparison on basis of RPM

With respect to the air velocity, different blade types generate different RPMs. Straight type blades have least RPM and thus have lowest performance with respect to rotation. Twisted type blades have the highest performance based on rotation, but they have complexity in their design. So, the curved blade types have high rotation performance and simpler design.

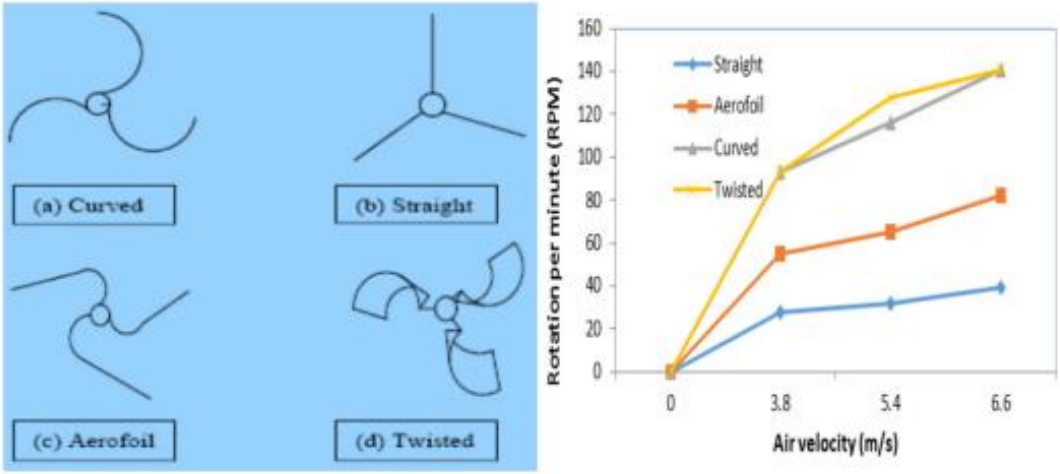

Figure 7 Blade Designs and variation of baldes' RPM with wind speed [24]

2.6 Solar Energy Harvesting

The technique of capturing and using solar energy for different purposes is known as solar energy harvesting. It involves capturing the sun's natural light and transforming it into useful energy. Utilizing solar energy decreases dependency on traditional energy sources and helps to lessen negative environmental effects. It is a renewable and sustainable solution.

Solar energy may be utilized in a variety of ways with the use of specialized technology. It may be transformed into electrical energy utilizing photovoltaic systems, which use semiconductor materials to directly convert sunlight into electricity. To generate steam for use in industrial operations or to heat water or other surfaces, solar thermal systems may also be utilized to capture solar energy.

Solar energy harvesting is the technique of absorbing sunlight using special objects or materials created to capture and transform its energy. To supply power to electrical devices, supply cooling and heating, as well as assist larger-scale services like powering residences or delivering power to the grid, the gathered energy may subsequently be stored or utilized right away.

Harvesting solar energy provides several benefits. It is a source of energy that is renewable and clean, which means it doesn't emit hazardous gases or have an impact on global warming. It is plentiful and unrestricted, especially in sunny areas. Additionally, solar energy systems need minimal maintenance, have long lifespans, and may eventually result in cost savings.

2.7 Solar Panels or Photovoltaic cells

Solar panels, sometimes referred to as photovoltaic (PV) panels, are equipment that use the photovoltaic effect to transform sunlight into useable electrical energy. They are made up of several photovoltaic cells that are linked.

The main components of solar panels are photovoltaic cells, often known as solar cells. These batteries' semiconductor components, including silicon, have unique features that make it easier to convert sunlight into power. Photons from the sunshine excite the semiconductor material's electrons as they hit the solar cell, creating an electric current.

To reach the necessary voltage and current levels, the photovoltaic cells are often linked in series or parallel inside a solar panel's grid-like arrangement. The solar cells' produced electricity can be utilized to immediately power electrical equipment, kept in batteries that can be use later, or sent into the electrical grid.

There are many different sizes and varieties of solar panels. A single crystal structure is used to create monocrystalline panels, whereas several crystal structures are used to create polycrystalline panels. A thin semiconductor layer is deposited onto a substrate to create thin-film panels.

Solar panels are extensively employed in both residential and commercial uses, from modest rooftop installations to massive solar farms. By using plentiful solar energy, they offer a sustainable and eco-friendly source of electricity. Solar panels are a dependable and affordable option for producing clean energy because of their extended lifespan and low maintenance requirements.

2.8 Hybrid Solar-wind power generation

A system that uses both solar energy and wind energy to produce electricity is referred to as a hybrid solar wind power production system. To maximize energy output and raise the overall effectiveness of the power generation system, it takes use of the complimentary nature of solar and wind resources.

Solar panels are used in a hybrid solar-wind power generating system to collect sunlight and employ photovoltaic (PV) technology to transform it into electrical energy. At the same time, wind turbines are used to capture wind energy and use the rotation of their turbine blades to transform it into electrical energy. For a more stable and dependable source of power, solar and wind energy are combined into one system.

A hybrid energy system that combines solar and wind energy sources has various benefits. First, increased energy creation is made possible by the fact that wind and solar energy may both be produced during the day and night. Solar energy production is normally at its peak during the day. This makes it possible to produce electricity more consistently and dependably.

The hybrid system also benefits from many environmental factors. For instance, wind energy may be more plentiful when the amount of sunshine is low, maintaining a steady supply of energy. Like this, solar energy may make up for decreased wind power generation in areas where the speed of the wind is limited during particular seasons.

A hybrid solar-wind power generating system may also make the best use of available land and infrastructure. In comparison to individual solar and wind installations, the system may be made more space-efficient by integrating solar panels and wind turbines.

The total sustainability and environmental advantages are also enhanced using solar and wind energy in a hybrid system. Utilizing renewable energy sources lessens dependency on fossil fuels and aids in reducing air pollution and greenhouse gas emissions.

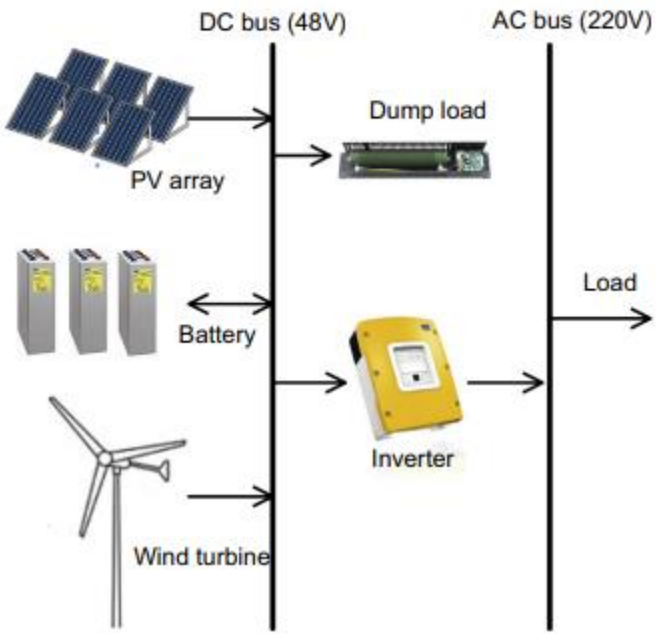

Figure 8 Flow diagram of a hybrid solar–wind system with battery storage. [32]

Chapter 3: Design Methodology

3.1 Design Approach

A vertical axis windmill and solar panels are combined as part of the design of the hybrid energy harvesting system to effectively convert solar and wind energy into electrical energy. With vertical blades, the vertical axis windmill can collect wind from any direction, maximizing its ability to gather energy. The windmill's rotating blades transform the wind's energy into mechanical energy. Additionally, solar energy is converted into electrical energy through PV processes when solar panels are carefully positioned to absorb sunlight during the day. The central shaft of the windmill and the solar panel system are both connected to an electrical generator, which transforms the mechanical energy of the windmill and the solar energy from the panels into electrical power.

The electrical energy produced is stored in rechargeable batteries to maintain a constant power source. These batteries serve as a reservoir, enabling the storing of extra energy generated during periods of strong winds or plenty of sunshine, which may subsequently be used during times of weak winds or scant sunlight. To ensure effective energy utilization and optimize the charging and discharging processes, a power management system is put in place to control the flow of energy between the windmill, solar panels, and battery storage.

A mobile application is created as a component of the system to improve user engagement and offer insightful data. Users may view a real-time dashboard of the battery state, energy output, and consumption thanks to this application's user-friendly design. Remote data access, performance-related warnings, and energy use trends tracking are all available to users. By giving users a thorough awareness of their energy usage and encouraging energy-saving behaviors, this mobile app intends to empower consumers.

In conclusion, the vertical axis windmill and solar panels are integrated into the design of the energy collecting system, allowing for the conversion of solar and wind energy into electrical energy. The system makes sure that there is always a power supply, and that energy is used effectively by including battery backup and a power control system. By offering real-time monitoring and control, the mobile application improves user experience by making it possible for users to actively engage in energy management and embrace sustainable procedures.

3.2 Material Selection

To achieve the best performance and longevity, much thought went into the material selection for our kinetic energy collecting system throughout design and construction. The vertical axis windmill's wings, which are an essential part of our system since they are so effective at gathering wind as well as solar power. We decided to use aluminium as the main component of the wings after thorough consideration.

Aluminum is a fantastic option for our application because of its many beneficial qualities. First, even under low wind conditions, the windmill can rotate smoothly and effectively since aluminum is both lightweight and durable. The system can successfully harness energy while retaining structural integrity because to its high strength-to-weight ratio. Furthermore, aluminum has superb corrosion resistance, assuring the lifetime and toughness of the wings in a variety of climatic circumstances.

The ability of the material to convert solar energy was another important consideration. The method works best when solar panels are integrated using aluminum as the material of choice. Due to its excellent thermal conductivity, heat can be effectively dissipated, preventing solar cells from overheating and increasing their overall efficiency. Additionally, aluminum is readily recyclable, which supports the environmental objectives of our project.

3.3 Electrical Components

3.3.1 Arduino

A freely available microcontroller platform called Arduino enables you to design and programme a variety of electronic devices. It includes a microcontroller, an input/output board that can be programmed, and a development platform for creating and uploading code. Since they are simple to use and accommodate a variety of sensors and actuators, Arduino boards are frequently used for creating and developing interactive applications.

Although there are many different sizes and forms of Arduino boards, they generally have a tiny, compact form factor. The board has an embedded microcontroller that acts as the system's central processing unit. The microcontroller oversees carrying out the instructions in the programmes and communicating with the linked components.

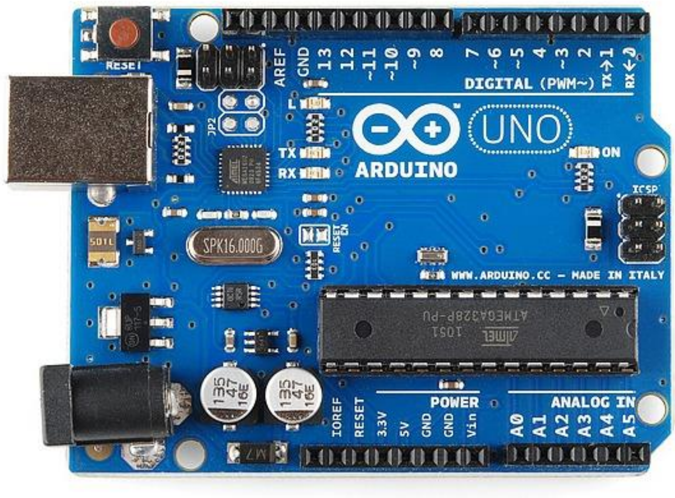

Figure 9 Arduino Uno

3.3.2 Buck Convertor

An electrical system known as a buck converter, often called a step-down converter, is frequently used to transform a higher voltage level into a lower voltage level. It is an effective way for regulating voltage and is used in many different electrical devices and systems. A buck converter's principal job is to reduce the voltage that it receives while keeping the output voltage steady and under control. Combining inductors, capacitors, diodes, and transistors—typically in a switching configuration—allows for this.

By controlling the duty cycle of the switch, the buck converter can efficiently step down the input voltage to provide a regulated output voltage that is lower than the input. Buck converters are widely used in various applications, including power supplies for electronic devices, battery charging systems, and voltage regulation in automotive and industrial applications.

Figure 10 Buck converter

3.3.3 Motor

An electromechanical device called a DC motor transforms electrical energy into mechanical motion. The magnetic field created by the electric current flowing through the motor interacts with the magnetic field produced by the permanent magnets or field coils. The motor shaft rotates as a result of this interaction's creation of a rotating force. A direct current, or DC, motor that can also function in reverse as a generator, creating electrical energy when physically driven, is referred to as a 24V DC motor operating as a generator. Due to a phenomenon known as "back electromotive force" (back EMF), this is possible. The magnetic field produced by the field coils or permanent magnets produces a voltage in the motor's wires when the motor shaft rotates. When the device was acting as a motor, the voltage that was applied that powered it was in opposition to the induced voltage. The produced voltage is a function of both the magnetic field's intensity and the rotational speed. The system receives mechanical energy when the engine shaft rotates. The DC motor, acting as a generator, transforms this mechanical energy into electrical energy. Other devices may be powered by the electrical energy produced, or it may be saved in batteries for future use.

3.3.4 Bluetooth Module

A little electrical gadget called a Bluetooth module makes it possible for diverse devices to communicate wirelessly with one another across short distances. It is based on Bluetooth technology, which creates links and enables data transfer via radio waves. The module functions as a transceiver, enabling smooth communication between gadgets like smartphones, tablets, PCs, and other compatible gadgets. It normally comprises of an antenna, a Bluetooth radio, and a microprocessor that are all included in a single unit. It is appropriate for a variety of programmes, including wireless sound broadcasting, Internet of Things devices, smart homes, and more since it can broadcast and receive data like audio, visuals, and control signals. The Bluetooth module provides a dependable and practical wireless solution that makes it possible for devices to communicate quickly and effectively without the use of physical connections or laborious setup processes.

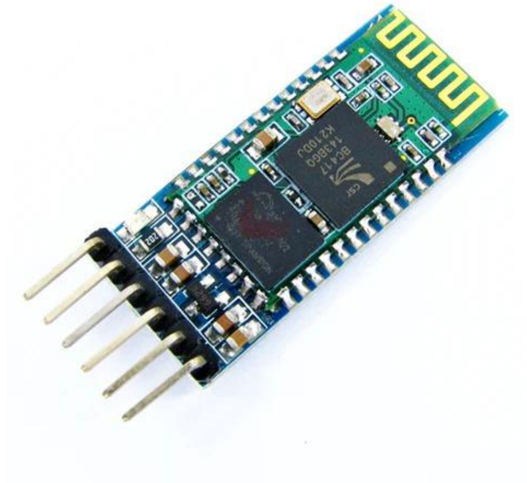

Figure 11 Bluetooth module

3.3.5 Temperature and Humidity Sensor

A temperature and humidity sensor is a tool used to gauge and keep track of the relative humidity and temperature of an area. It is made up of built-in sensors that can find and measure the amount of heat and moisture in the air. To precisely detect temperature and humidity levels, the sensor generally combines electrical components and cutting-edge sensing elements. In many different applications, including prediction of the weather, HVAC systems, agriculture, interior climate management, and industrial operations, it delivers real-time data. Temperature and humidity are physically measured by the sensor, which then transforms those measurements into electrical signals that may be processed, presented, and analysed or utilised to start automated processes. It is an invaluable instrument for preserving ideal environmental conditions and assuring effective operation in a variety of sectors due to its small size, simplicity of integration, and high accuracy.

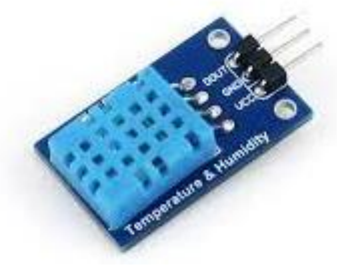

Figure 12 Temperature and humidity sensor

3.3.6 PCB

There are two PCBs used in out project:

1. Voltage Divider: This PCB takes the voltage from the battery and divides it by 10 and the resultant value is seen on the LCD.
2. 12V-5V Convertor: This PCB converts the 12V signal of the RPM sensor to 5V. Its function also includes steading the pulsating signal of the RPM sensor.

3.3.7 Solar Panel

5W solar panels, commonly referred to as 5-watt solar panels, are miniature photovoltaic (PV) systems that use sunlight to produce energy. These panels are made to offer low-power solutions for a variety of applications, especially when power and space are at a premium. The "5W" in their name alludes to their power output, suggesting that under ideal sunshine circumstances, they may produce up to 5 watts of electricity. These panels generally consist of several solar cells that use the photovoltaic effect to turn sunlight into energy. The solar cells are often constructed of semiconductor materials like silicon.

5W solar panels are frequently employed in portable electronics and small-scale applications because of their lightweight design and low power output. They are frequently discovered in tiny electrical devices, camping gear, and outdoor solar-powered lighting. These panels are simple to incorporate into backpacks, tents, and other portable buildings, enabling users to use solar energy wherever they are. They are frequently used to power low-power electronic devices like cellphones, tablets, and GPS units as well as recharge batteries, which makes them practical in isolated locations or during crises.

As they produce energy without emitting hazardous gases or depleting precious resources, they provide a sustainable and ecologically friendly alternative to conventional power sources. Additionally, a variety of users may access them because to their modest size and simplicity of installation, enabling anyone to personally contribute to the creation of clean energy.

In summary, 5W solar panels are portable, low-power photovoltaic devices that use sunshine to create electricity. They offer a sustainable and renewable energy option and find use in portable electronics, exterior lighting, and small-scale electronics. These panels are vital for promoting sustainable energy and giving people the confidence to use solar power in a variety of scenarios, even though the amount of energy they produce may be restricted.

We have used two of these 5W solar panels and connected them in series to generate the maximum amount of energy.

3.3.8 RPM sensor

A particular kind of sensor used to gauge a machine or device's rotational speed is known as an RPM sensor (12V) N-P-N. It is clear from the "12V" that it uses a 12-volt power supply. N-P-N, which stands for "Negative-Positive-Negative," refers to the type of transistor employed in the sensor's circuitry. RPM sensor is frequently employed in automotive applications, such as determining the crankshaft speed of an engine or the wheel rotation rate. It may also be used in robots, industrial machinery, and other systems where keeping track of rotational speed is essential for efficiency and security.

The sensor detects variations in the magnetic field brought on by the rotating element that serves as its mode of operation. It consists of a transistor-based circuit and a magnetic pickup. As the magnetic pickup moves through a magnetic field, a tiny voltage is produced, and this voltage causes the N-P-N transistor to turn on or off. The RPM sensor is able to precisely calculate the speed of rotation of the target element by measuring the quantity of switching events that occur during a predetermined period of time. The sensor must receive a stable and adequate voltage in order to function dependably, which is why a 12V power source is necessary. Usually, the electrical system of the car or an outside power source supplies this voltage.

Figure 13 RPM sensor

3.3.9 LCD Module

A common electrical component for showing information visually is an LCD (Liquid Crystal Display) module. It is made up of two transparent electrodes and a flat panel with liquid crystals sandwiched between them. The LCD module makes use of liquid crystals' special abilities to modify their optical characteristics in response to an electric field. Many different electronic products, such as devices such as calculator’s electronic watches, smartphones, tablets, TVs, and computer displays, employ LCD modules. They are perfect for portable devices because to their many benefits, including energy efficiency, lightweight construction, and small size. Its programming is done on Arduino software.

Figure 14 LCD Module

3.4 Battery Selection

A 12V lead battery is a commonly used standard in a variety of applications, including backup power systems and automobiles. The use of a 12V battery is a sensible decision for compatibility because many gadgets and pieces of equipment are made to function with a 12V power source.

The lead battery's 7.6 AH capacity strikes a balance between size and power output. It has a respectable amount of ability, allowing for the storage of a fair quantity of energy without being excessively big or heavy. It is suitable for a range of applications, such as in electric vehicles, energy storage systems, electrical power supply systems also called UPS, and other equipment that require a moderate amount of power for a short period of time. Lead batteries are often utilized. They are well known for being less expensive than alternative battery technologies. They are a desirable substitute because of their low cost, particularly when the software being used doesn't require quick charging or high energy densities.

Lead batteries are well known for their durability and strength. They have a history of achievement in a variety of industries, and it is well understood how they interact chemically. When handled and utilized correctly, they are generally thought to be safe. In addition, lead batteries are well known for their ability to sustain a steady voltage output throughout the discharging process, making them a reliable power source for jobs needing continuous performance.

3.5 Energy conversion Mechanism

The mechanism used is a rotation of a turbine, which converts mechanical energy into electrical energy. The turbine's spin causes a shaft linked to it to experience rotational motion. Because of the spinning of the shaft, the conversion of mechanical energy to electrical energy starts. The bottom of the rotating shaft has a wheel attached to it. The wheel rotates with the shaft as it rotates. This wheel is frequently constructed of a softer material to promote friction reduction and smooth motion. This wheel rotates because of the torque that the spinning shaft produces. The first wheel is attached to a second wheel made of soft material.

The energy conversion happens during the second wheel's revolution. It is attached to a motor that can transform mechanical energy into electrical energy. The motor produces electrical energy by turning as the second wheel propels it.

In conclusion, the spinning of a turbine, which in turn turns a shaft, is the process for energy conversion in this system. A wheel receives the shaft's rotating motion and then drives another wheel. A motor is driven by the rotation of the second wheel, which produces electricity. Through this method, mechanical energy from the turbine may be efficiently converted into electrical energy.

Chapter 4: Modeling and Simulation

4.1 Mechanical Structure

The length of the wings of the VAWT is 57.15 cm and its diameter is 28cm. The sheets above and below are 0.4 cm. Below the wind turbine is a box of 34 cm the width of 32 cm. The overall structure is of 81 cm. There are two solar panels mounted on top of the frame. On the box there is a flap where the electrical circuit is present. Inside the box we can see the shaft of the windmill connected to a wheel making it rotate with it and that wheel turns another wheel that in turn gives the mechanical energy to the motor to generate electrical energy.

4.2 CAD Model

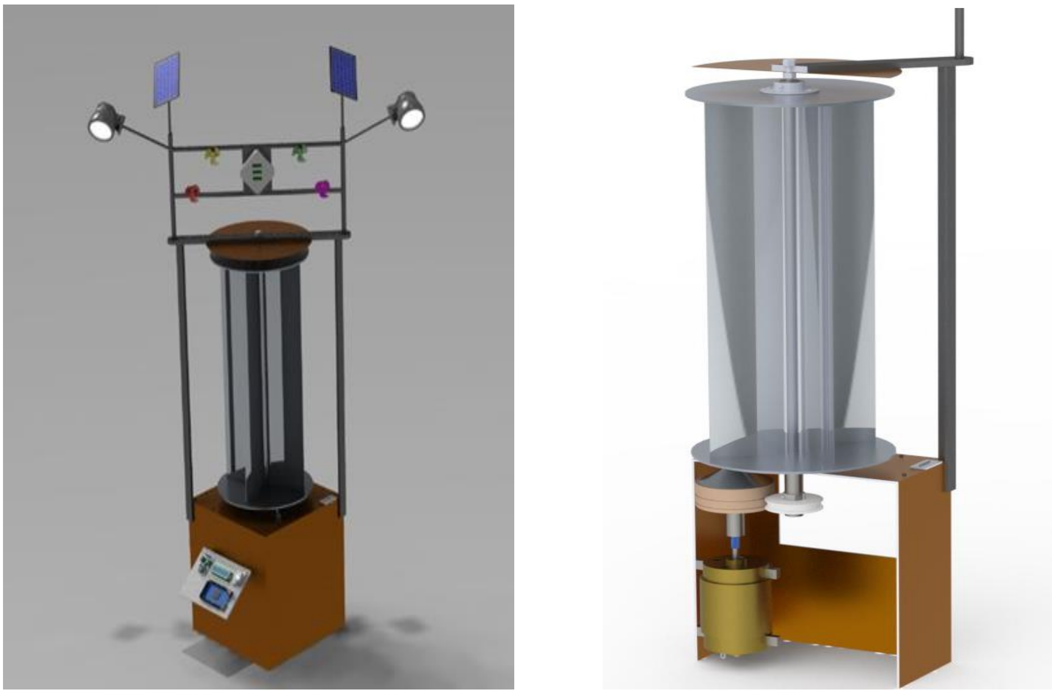

Figure 15 CAD Model

The flow animation was also done on SolidWorks and we can get a better look at the model and its working on that.

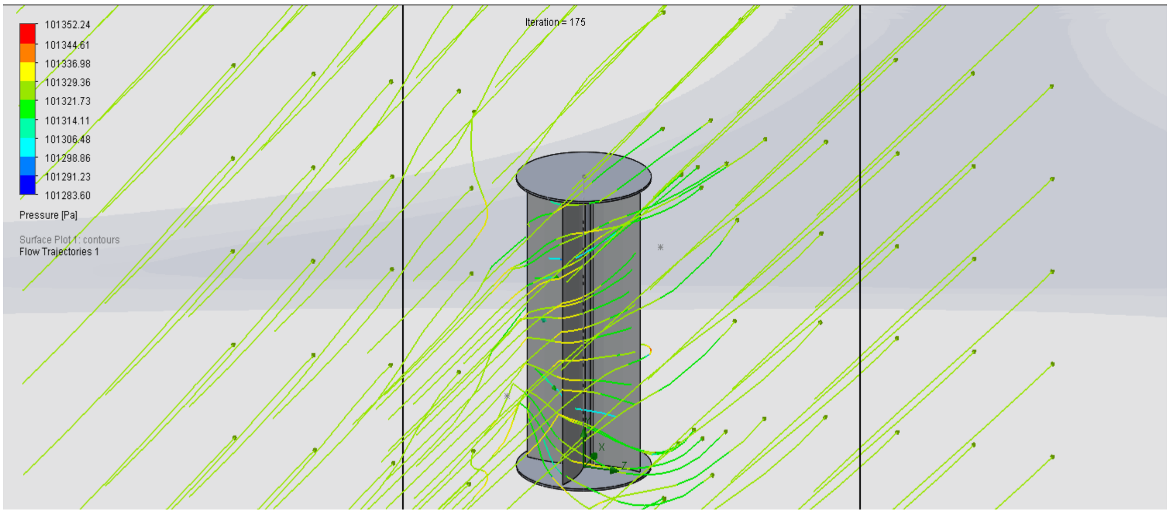

Figure 16 Wind flow on Solidworks

4.3 Analysis

We used this model on ANSYS to get a value of Torque. The analysis was done on ANSYS Fluent and was 3D, double precision, pressure-based, dynamic mesh.

4.3.1 Mesh Size

The mesh size of the rotating body was 20mm and that of the windmill face was 2.25mm. For the stationary body the mesh size of the extracted windmill (cylindrical faces) was 20mm and that of other stationary objects was 30mm.

4.3.2 Mesh Type

On the rotating body we used the Multizone method and the mapped mesh type prism and pre mesh tetra were used. For the stationery we used the Multizone method and used mapped mesh type hexa/prism. Pre mesh was not allowed.

4.3.3 Inflation

The boundary on inflation was the turbine face and the option selected was total thickness. There were 3 number of layers with a growth rate of 1.3%.The maximum thickness was 2.25 mm.

4.3.4 Output

To get the output desired we had set up the date to 11 iterations with each time step being 0.85 seconds. The total number of time steps calculated was 250-time steps.

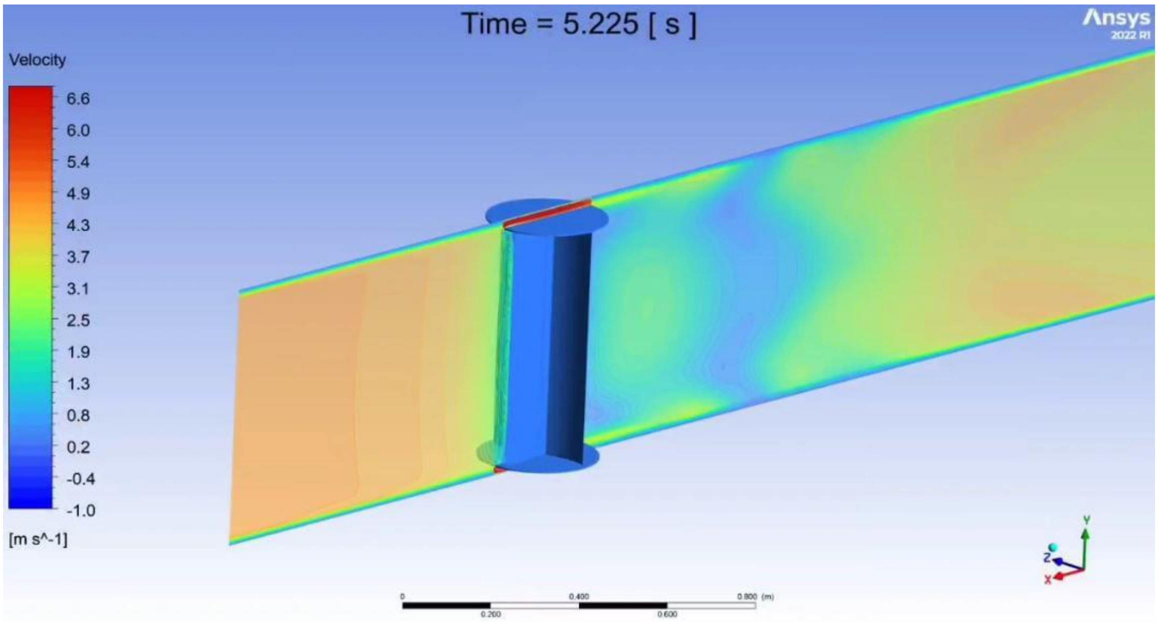

Figure 17 Velocity flow on ANSYS

Here you can see that the wind comes at a high speed and then rotates the wind turbine. The continuity as seen in the graph below is below 1 as it should be. The values of k and epsilon show us the characteristics of turbulent flow.

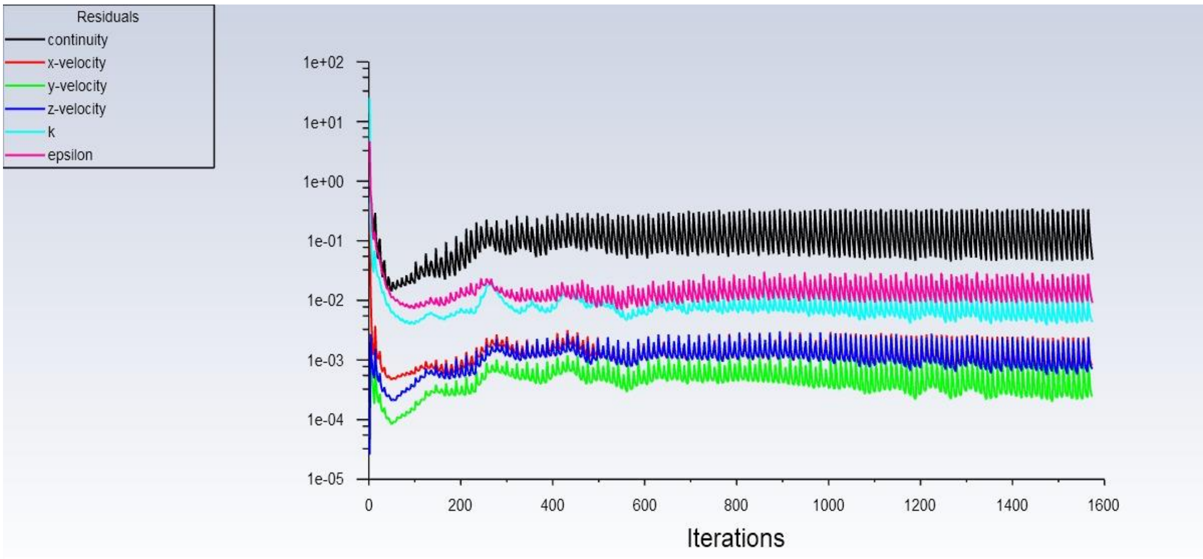

Figure 18 Resultants on ANSYS

The value we required was of torque which came out to be 0.2280767 N m. This is the average value of torque produced on our wind turbine. Further calculations can be done by this.

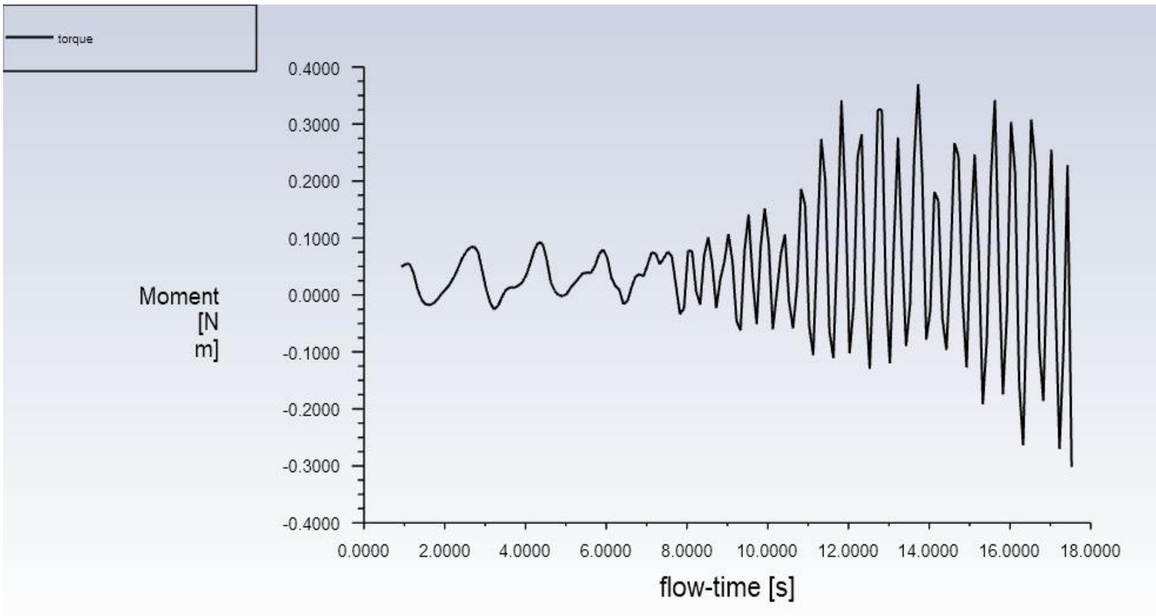

Figure 19 Torque output from ANSYS

Chapter 5: Fabrication

5.1 Electrical Implementation

The electrical components are connected to make a circuit that works on 5V. The Arduino is the center of the whole circuit. It is connected to the PCB that then connects to the RPM sensor. The battery is connected to the voltage divider PCB to the Arduino. The buck convertor, Bluetooth module and temperature and humidity sensor is also connected.

There is a buzzer connected too that makes the sound when the device is turned on and also when the battery is filled.

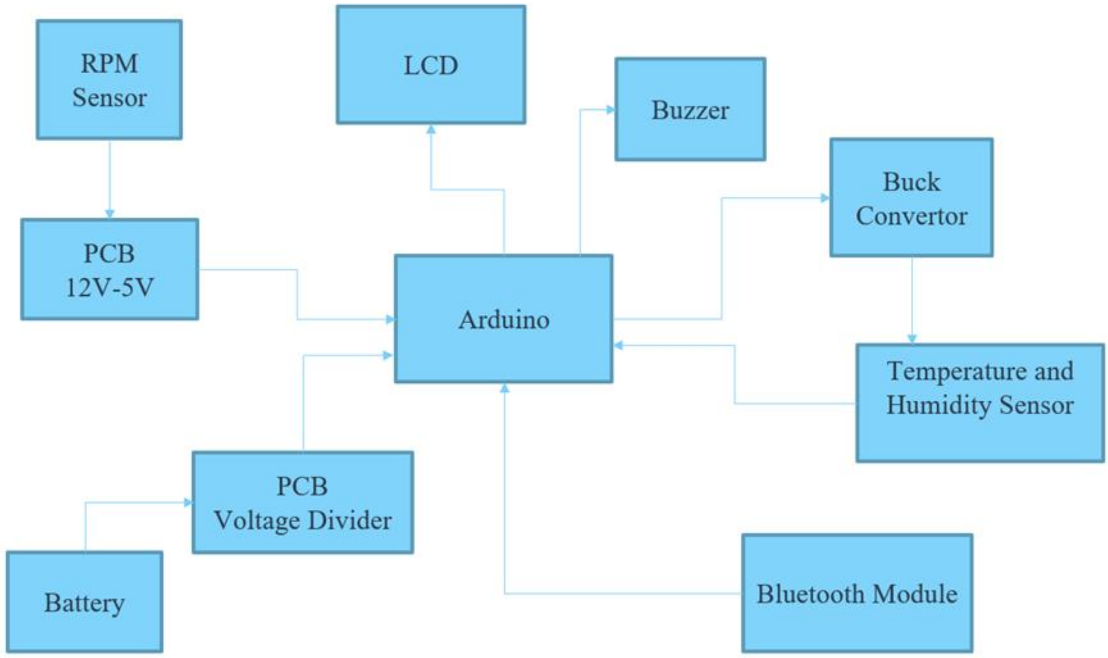

Figure 20 Schematic of Electrical circuit

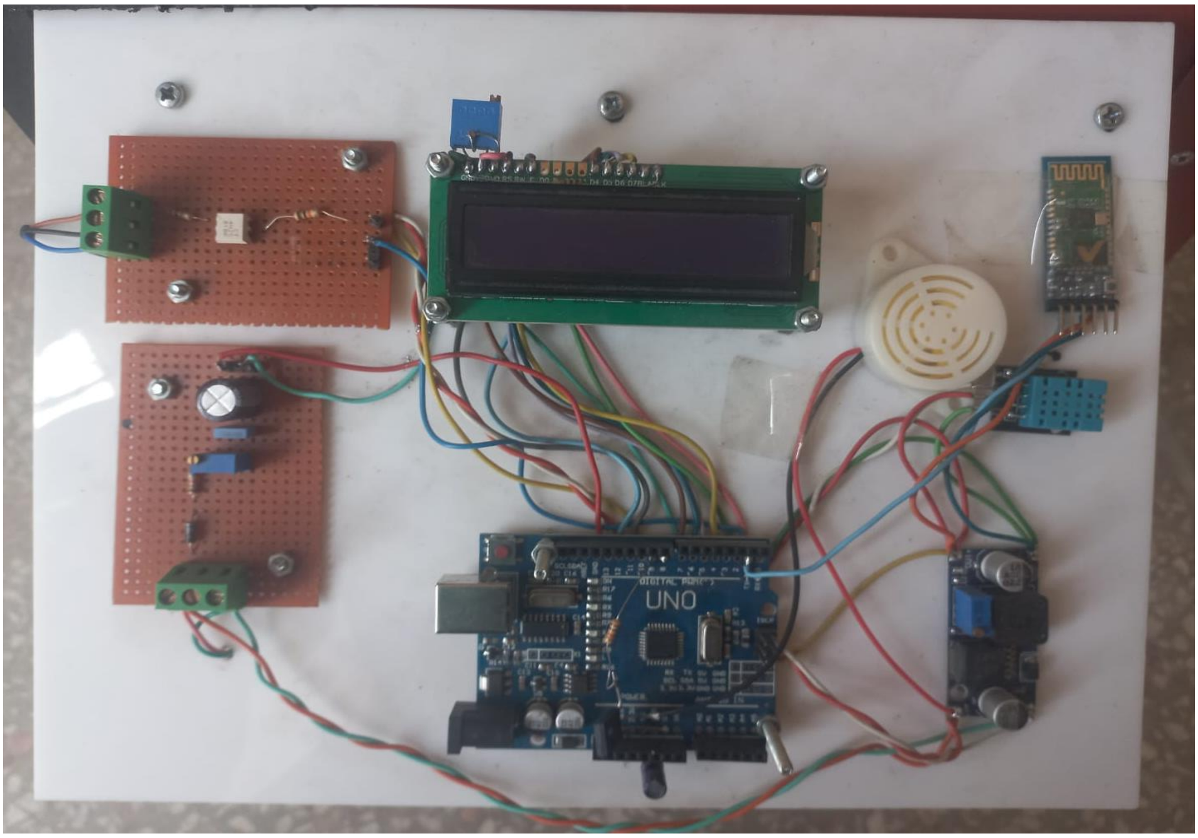

Figure 21 Electrical circuit

5.2 Mechanical Fabrication

A vertical axis wind turbine was the first thing that the project designed and built. The team opted to employ a Savonius type wind turbine in light of study findings. These turbines are distinguished by their curved, S-shaped blades, which can collect wind energy from any angle. A device with two synchronized wheels was created to transform the mechanical energy generated by a windmill into electrical energy. These wheels were created to turn in reaction to the turbine blades' rotation. The process would next include harnessing the mechanical energy from the turning wheels to create electricity.

A sliding panel was added to one facet of the box to provide simple display and access to the system's electrical components. This slide mechanism made it possible to inspect and maintain the electrical components, such as cables, connections, and control circuits, with ease. The various components were welded together to form an assembly that was placed on top of the enclosed system. The energy conversion system and wind turbine were supported and stabilised by this unit. In order to facilitate the insertion of solar panels and lighting, a framework was weld onto the assembly. This improvement improved the system's overall ability to generate energy by enabling the incorporation of solar energy as a supplemental power source.

The wiring linking the different parts, including the wind turbine, the power conversion system, the solar panels, the lights, and the batteries, needed to be connected as the last phase. This wiring allowed for effective energy conversion and storage by ensuring that power flows properly throughout the system. The model was prepared for testing once all the parts were put together and attached. The solar panels took in sunlight while the wind turbine was subjected to wind flow. Through the mechanical movement of the wheels and the transformation of solar energy, the system would produce electricity, which could either be stored in the battery or utilised to power the associated lights.

5.3 Schematic

The windmill and solar panels are the main parts of the schematic for our energy harvesting system. The windmill's construction allows it to catch wind energy in any direction, maintaining efficiency even amid turbulence. The solar panels are placed such that they may absorb sunlight and produce electricity from it. A charge controller, which is connected to both energy sources, controls the power that comes in and makes sure the battery is charged to its full potential. The battery serves as an energy storage device and has the capacity to store extra electrical energy produced by the solar and wind energy sources. An inverter that is attached to the battery transforms the DC (direct current) energy it stores into AC to power multiple devices. Additionally, we have a mobile charger attached to show our output and have added lights as the source to visualize the energy gathered. Overall, our design integrates the different parts to produce a harvesting system that is dependable and effective and makes the best use of solar and wind energy to produce sustainable electrical power.

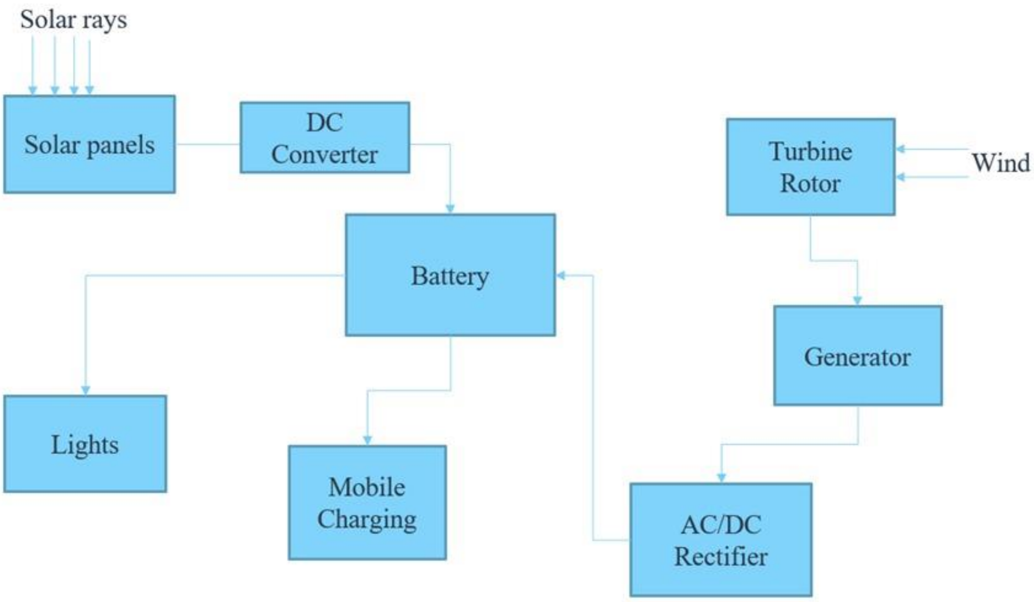

Figure 22 Process Schematic

Chapter 6: Theoretical Values

6.1 Mathematical Model

The mathematical model of this project gives us the values of output of power for this given model. The formulas include:

Tip speed ratio:

$$TSR = \frac{Vrotor}{V}$$

$$= \frac{\omega R}{V}$$

Where, Vrotor is the speed of turbine, V is the speed of wind, R is the radius of rotor.

Total power available from wind can be calculated using the following formula.

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

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

Where, ρ is the density of wind, A is the swept area of rotor.

Maximum power obtained from wind can be calculated using following formula.

$$P_T = T \times \omega$$

Where T is the actual torque develops by the turbine rotor.

Coefficient of Power can be calculated using.

$$C_P = \frac{P_T}{P}$$

Torque Coefficient:

$$C_T = \frac{T}{T_w}$$

Where T_w is the theoretical torque that can be obtained using following formula:

$$T_w = \frac{1}{2} \times \rho \times A \times V^2 \times R$$

6.2 Calculations

The swept area A of the turbine rotor can be calculated as;

$$A = N \times \pi \times R2$$

Where N is the number of blades of the turbine, i.e

$N = 4$

R is the radius of the turbine rotor,

$R = 0.14m$

Therefore;

$$A = 4 \times 3.14 \times (0.14)^2$$

$$A = 0.246\ m^2$$

Tip speed ratio:

$$TSR = \frac{Vrotor}{V}$$

V_{rotor} is the velocity of turbine rotor and V is the speed of wind.

Wind velocities are calculated using anemometer and turbine velocities are calculated using the RPMs it generated.

For rotor's RPM of *120*, velocity can be calculated as follows,

$$Vrotor = R\omega$$

Where ω is the angular speed of rotor in rad/s, therefore.

$$V_{rotor} = (0.14) \times (120 \times 2\pi/60)$$

$$V_{rotor} = 1.758\ m/s$$

Similarly, rotor's speed can be calculated using same method at corresponding wind speeds.

Therefore, Tip speed ratio for wind speed of $3.7\ m/s$ and rotor speed of $1.758 m/s$ is:

$$TSR = 1.758/3.7$$

$$TSR = 0.4752$$

Total power available from wind for wind speed of 3.7m/s is;

$$P = ½ \times \rho \times A \times V^3$$

$$P = 8.0558\ W$$

Theoretical torque available in wind for a wind velocity of 3.7 m/s is

$$T_W = ½ \times \rho \times A \times R \times V^2$$

$$T_W = 0.3048\ Nm$$

All the calculated values are given below in Table 1

Table 1 Calculated Values

Wind speed m/s	Turbine's RPM	Turbine speed m/s	Tip Speed Ratio	Total power available from wind Watts	Theoretical torque Nm
3.2	60	0.8792	0.27475	5.211389952	0.22799831
3.7	120	1.7584	0.475243	8.055802467	0.304814147
4.1	160	2.344533333	0.571837	10.96112692	0.374282383
4.6	180	2.6376	0.573391	15.4802201	0.471137134
4.9	200	2.930666667	0.598095	18.71077931	0.534593695
5.2	240	3.5168	0.676308	22.36215571	0.602058038
5.7	270	3.9564	0.694105	29.45290953	0.723404795

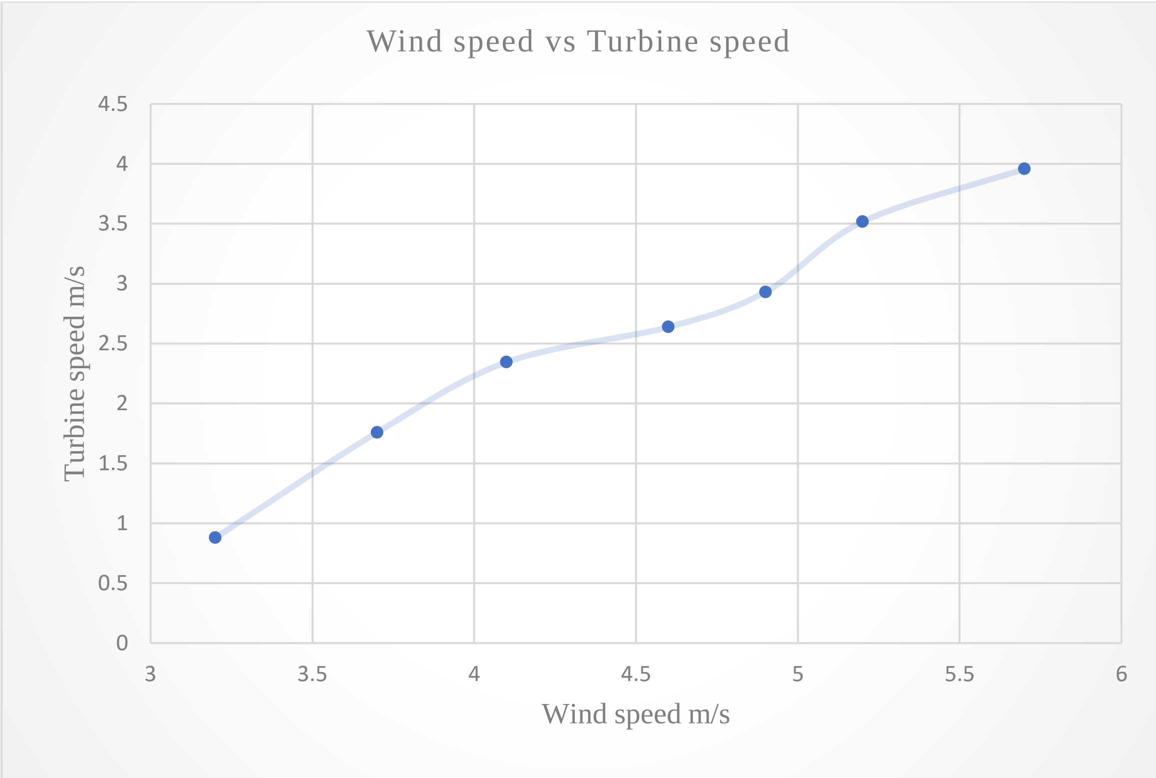

Figure 23 Graph of wind speed vs Turbine speed

Figure 24 Graph of wind speed vs Tip speed ratio

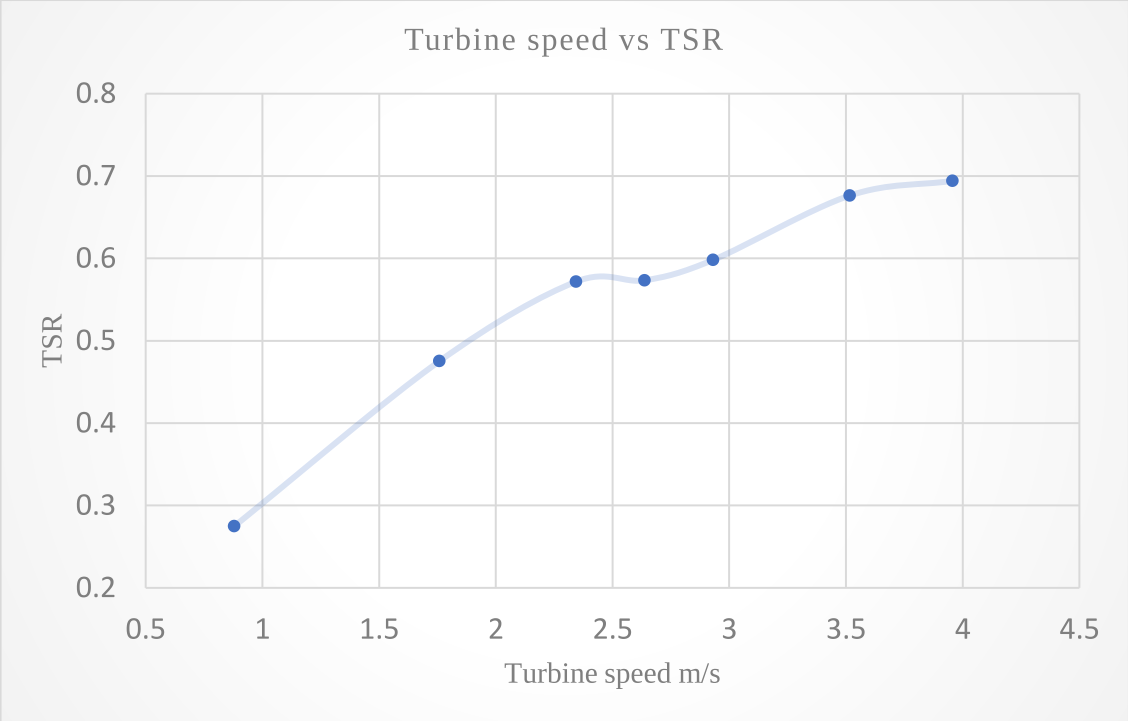

Figure 25 Graph of turbine speed vs Tip speed ratio

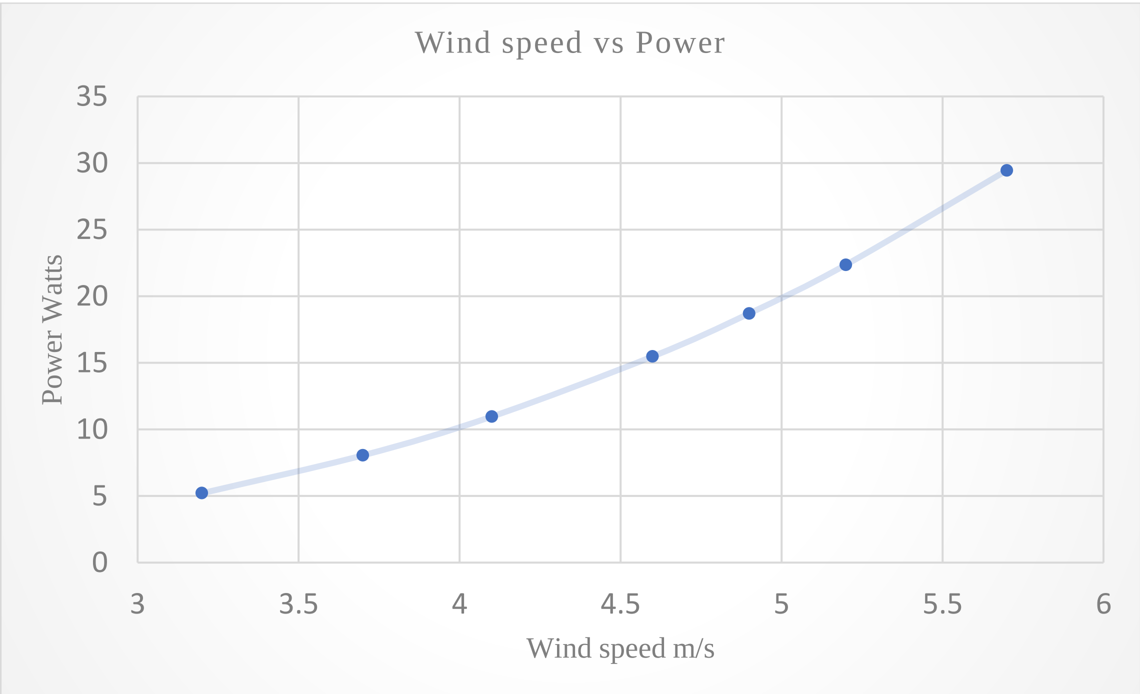

Figure 26 Graph of wind speed vs Power

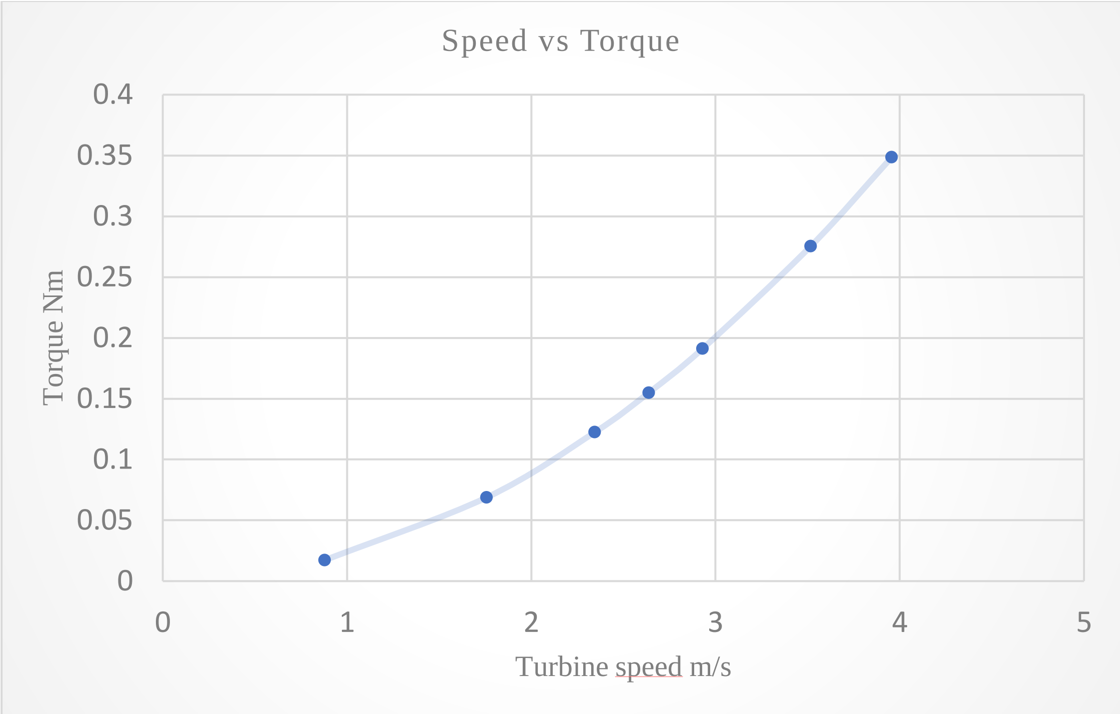

Figure 27 Graph of turbine speed vs torque

6.3 Solar Values

Table 2 shows the estimated values of solar energy that should be produced on average monthly. These theoretical values are for the area Rawalpindi, Pakistan. The software used for these values is RETScreen.

Table 2 Estimated values of average solar energy

RESULTS

Print Results

74 kWh/Year*

Month	Solar Radiation (kWh / m² / day)	AC Energy (kWh)
January	3.93	5
February	4.55	5
March	6.05	7
April	6.49	7
May	7.28	8
June	7.01	7
July	6.39	7
August	5.99	6
September	6.12	6
October	5.69	6
November	4.74	5
December	3.97	5
Annual	5.68	74

Chapter 7: Mobile Application

7.1 MIT App Inventor

We used MIT app inventor to create a Bluetooth operated application. The purpose of this application was to monitor the data of the project. It shows the RPM value, the temperature of the surroundings, the humidity percent of the surroundings and the battery voltage.
MIT app inventor is an online software that helps you design and implement the features you desire in your application. The benefits for using this was that we got the full tutorials of our requirements.
The interface of the mobile application is shown below.

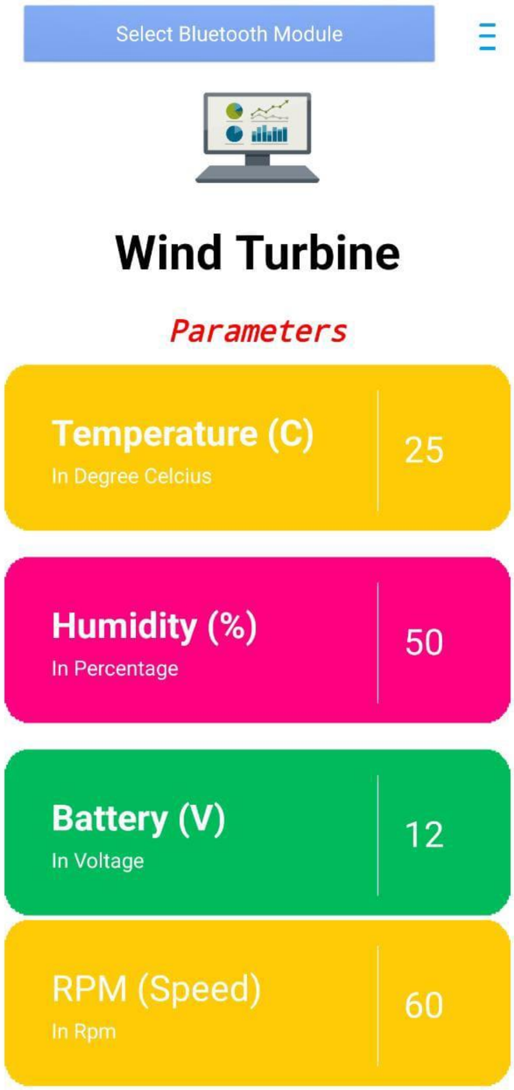

Figure 28 Mobile Application

Chapter 8: Evaluation

8.1 Economic Impact

By utilizing renewable energy sources like solar and wind, the project can contribute to long term reductions in power prices, particularly in regions with abundant wind and sunshine resources. The installation and upkeep of the kinetic energy collecting system may call for specialized labor, which can help to boost employment and the economy.

8.2 Environmental Impact

By encouraging the use of renewable energy sources, the initiative hopes to lessen dependency on fossil fuels and the resulting greenhouse gas emissions. Also, by utilizing solar and wind energy, the system can help to reduce carbon dioxide emissions, hence reducing the effects of climate change. The initiative decreases the consumption of scarce resources like fossil fuels by using readily accessible energy sources, encouraging sustainability.

8.3 Social Impact

This project helps build a societal effect by putting in place a system like this, it is possible to bring electricity to isolated or off-grid locations, enhancing access to energy and promoting socioeconomic advancement. The usage of renewable energy can lower air pollution, resulting in better air quality and fewer respiratory issues, both of which are good for public health. The initiative can encourage community education and information sharing while increasing public awareness of renewable energy technology.

8.4 Future Scope

An energy harvester that combines solar energy conversion with a vertical axis windmill has a bright future. Some potential directions for future growth and development include:

- The advancement of technological progress can be done. The energy harvesting system's efficiency may be improved by further research and development, allowing for higher energy conversion rates and better performance under a variety of wind and sun situational factors.

- New developments in the field of energy storage, such as batteries or other creative solutions, can increase the amount of energy that can be stored, extend the autonomy of the system, and enhance the efficiency with which the energy is used.
- By combining kinetic energy collecting technology with other renewable energy sources, such as solar or tidal power, hybrid systems can optimize energy output while also enhancing dependability. The creation of integrated grid methods would enable the system's excess energy to be transferred back into the grid, encouraging a more autonomous and robust energy infrastructure.
- The technology may be improved for use in cities, where vertical axis windmills may be incorporated into structures, infrastructure, or open spaces to capture wind energy even in heavily populated regions. Expanding the use of these systems in rural and off-grid areas can give residents their access to inexpensive, sustainable energy, enhancing their quality of life and means of subsistence.
- By integrating IoT technology, kinetic energy harvesting systems can be remotely monitored, controlled, and optimized, increasing their operational effectiveness, and lowering maintenance costs. Advanced analytics may be used to optimize energy output, forecast maintenance requirements, and offer insightful information for system enhancements using the data gathered from the system.

In general, technical developments, scalability, integration with other energy sources, growing commercial applications, IoT integration, and supporting regulations and investments will determine the future potential of hybrid energy harvesting systems. These advancements may help create a more robust and sustainable energy environment.

8.5 Conclusion

Total Output Power is 6.16 Watts The hybrid solar wind power generating system should have a total output power of about 6.16 Watts in order to attain an efficiency of 28%.

The calculations showed that the hybrid solar-wind power generating system has a 28% efficiency. This proves that the system successfully transformed the whole amount of energy input from solar and wind sources into useable electrical energy. In conclusion, the hybrid solar wind power generating system shows how wind and solar energy sources may be successfully combined. A dependable and effective method of capturing renewable energy is provided by the system's capacity to produce electricity from the wind turbine and harvest energy from the solar panel.

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