DESIGN AND DEVELOPMENT OF ARTIFICIAL WIND TREE FOR OFF-GRID POWER GENERATION

A PROJECT REPORT

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BONAFIDE CERTIFICATE

Certified that this project report **"DESIGN AND DEVELOPMENT OF ARTIFICIAL WIND TREE FOR OFF-GRID POWER GENERATION"** is the bonafide work of **"PRANAV V SARMA(310614105066), RAHUL M(310614105077), RENGANATHAN R(310614105080), SAI PRASAD D(310614105084)"** who carried out the project work under my supervision.

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INTERNAL EXAMINER **EXTERNAL EXAMINER**

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DECLARATION

We hereby declare that the entire work contained in this project report entitled "**DESIGN AND DEVELOPMENT OF ARTIFICIAL WIND TREE FOR OFF-GRID POWER GENERATION"** has been carried out by us at Easwari Engineering College, Chennai under the guidance of **Dr. E. Kaliappan, M.Tech, Ph.D,** Head of the Department, Department of Electrical and Electronics Engineering.

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ABSTRACT

Wind energy and solar energy are considered to be the most reliable and efficient among other renewable energy sources. But the commercial windmills require large installation space, have high capital and maintenance costs, rotates only at high velocity and the output power is discontinuous and seasonal. Hence in this project, the above drawbacks are overcome by combining both wind and solar energy for power generation

In this project, the Wind tree is used to generate electricity with the help of Aero leaves and a solar panel. The panel and the five Aero leaves are placed in the form of a tree structure, called Wind Tree. Wind Tree uses the Aero leaves to generate power from wind energy and panel to generate power from solar energy. An Aero leaf is able to generate DC power using a dynamo regardless of the wind direction and with a cut-in speed of 5 kmph. Here the Aero leaves are made up of Savonius type wind turbine which captures the wind from all the directions. The power generated from the tree is stored in the battery, which then powers the load using an inverter. When the wind blows, the aero leaves rotate quietly and the tree produces energy of about 20W.

The power generated was analysed using a graph and hence concludes that the wind tree is suitable for those areas where continuous power generation, low maintenance are important factors and in places where conventional windmills cannot be set up. In future, the output power can be further improved by increasing the number of aero leaves and panels.

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LIST OF SYMBOLS AND ABBREVIATIONS

C_P	Betz co-efficient
RPM	Revolutions per minute
AC	Alternating Current
DC	Direct Current
KMPH	Kilometre per hour
HAWT	Horizontal axis wind turbine
VAWT	Vertical axis wind turbine
MW	Mega watt
MU	Million unit
UV	Ultraviolet
PMMA	Poly methyl methacrylate
PC	Polycarbonate
PMG	Permanent magnet generator
EMF	Electromotive force
PV	Photo voltaic
STC	Standard test condition
IC	Integrated chip
SMF	Sealed maintenance free
VRLA	Valve regulated lead acid
UPS	Uninterrupted power supply
PWM	Pulse width modulation
SMPS	Switch-mode power supply

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CHAPTER 1

INTRODUCTION

1.1 GENERAL

Wind energy is one of the most available and exploitable forms of renewable energy. Wind possesses energy by virtue of its motion. Despite the wind's intermittent nature, wind patterns at any particular site remain remarkably constant year by year. Wind speeds increase with increase with height. Average wind speeds are greater in hilly and coastal areas than they are in land.

Any device capable of slowing down the mass of moving air, like a sail or propeller, can extract part of the energy and convert it into useful work. Three factors determine the output from a wind energy converter, and they are

(i) Wind speed

(ii) Cross-section of wind swept by rotor

(iii) Overall conversion efficiency of the rotor, transmission system and generator

No device, however well designed, can extract all of the wind's energy because the wind would have to be brought to a halt and this would prevent the passage of more air through the rotor. A 100% efficient aero generator would therefore only be able to convert up to a maximum of around 60% of the energy available in the wind into mechanical energy. Well-designed blades will typically extract 70% of the theoretical maximum, but losses incurred in the gearbox, transmission system and generator could decrease overall wind turbine efficiency to 35% or less. Moreover, present wind energy conversion systems require average wind speeds of 6 m/s which is not achieved all the time, because of wind's inconsistent nature. They also require large landscape and frequent maintenance.

1.2 LITERATURE REVIEW

P. Clague, T. Z. Qi, *"A Novel Design Of A Savonius Wind Turbine Water Heating In Residential Settings"*, 2008 IEEE International Conference on Mechatronics and Machine Vision in Practice[9]. This paper presents a novel wind turbine design to provide heating for hot water storage systems in residential houses. Here a vertical axis wind rotor (Savonius type wind turbine) was developed. This design's output is applied to a resistive load to produce heat formed due to the dissipated power, which is subsequently used to heat water for residential use.

Md. Jahangir Alam, M.T. Iqbal, *"Design And Development Of Hybrid Vertical Axis Turbine",* 2009 IEEE International Conference on Electrical and Computer Engineering[13]. Power from wind or water current can be extracted using a horizontal or vertical axis turbine. This paper presents the design of a hybrid turbine based on a straight bladed Darrieus (lift type) turbine along with a double step Savonius (drag type) turbine. Four bladed Darrieus rotor is placed on top of a Savonius rotor. This paper presents the system design and performance test results of the hybrid turbine.

Pranit Nagare, Rammohan Shettigar, Arnav Nair, Pratibha Kale, Prasanna Nambiar, *"Vertical Axis Wind Turbine",* 2015 IEEE International Conference on Technologies for Sustainable Development[7]. The problem associated with Darrieus is the lack of self-starting while the Savonius has a low efficiency. In order to overcome these flaws, in this project, an innovative design has been created by incorporating both the types into one single unique structure. This unique design allows the use Savonius as a method of self-starting the wind turbine which the Darrieus cannot achieve on its own. The testing of the model was carried out for different wind velocities

Erol Kurt, Halil GÖR, *"Electromagnetic Design of a New Axial Flux Generator",* 2014 International Conference on Electronics, Computers and Artificial Intelligence[4]. This study presents the electromagnetic design of a new permanent magnet generator. The machine consists of two rotors at both sides and a stator between them. The rotors have 32 rare earth disc magnets in total and the stator has 24 coils. It is a three-phase machine which produces directly sinusoidal output. The simulations prove that the magnetic flux density of 0.6 T can be available in the air gap due to the usage of a core.

1.3 PRINCIPLES OF WIND TURBINE:

- NEWTON'S FIRST LAW & ROTATIONAL INERTIA:

If an object is moving at a constant velocity or is stationary, then the net forces acting on it must be equal to zero. The blades have rotational inertia proportional to their mass. A low rotational inertia is desirable while maintaining strength so that the turbine can accelerate from rest in light winds.

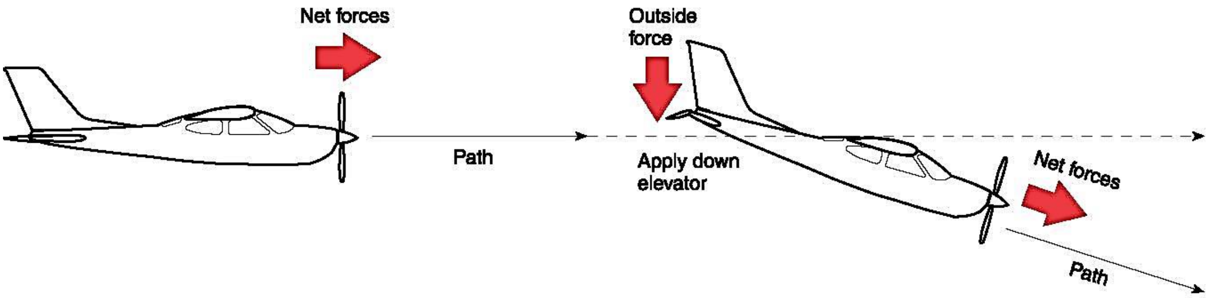

Figure 1.1 Newton's First Law

- NEWTON'S SECOND LAW

A change in velocity is acceleration. Acceleration indicates that an unbalanced force must be acting on the mass. It also states that "Change in momentum is equal to the impulse force". Wind turbines pick up some of their kinetic energy from the deflection of air as it hits the blades. Air blowing onto the blades of the turbine is forced to change its velocity at constant pressure. A change in velocity creates a change in momentum of the air mass which indicates that a force must be acting; as shown below in the figure 1.2

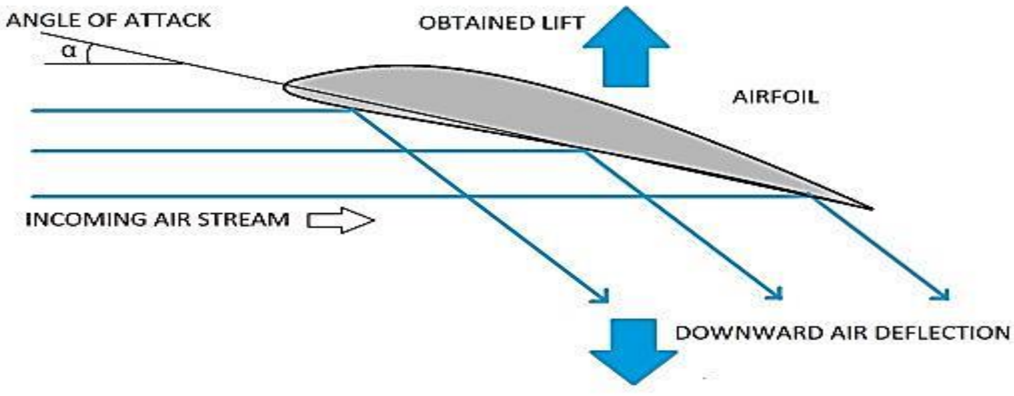

Figure 1.2 Newton's Second Law

- NEWTON'S THIRD LAW & REACTION TURBINES

"For every force that acts on an object, there is an equal and opposite reaction force exerted by the object". Air moving over the blades changes its local pressure due to the Bernoulli Effect. The difference in pressure between the top and bottom of the blades creates a tangential force over the blade area. The blade pushes down on the air and the air pushes up on the blade creating lift. The blade is 'reacting' to the difference in air pressure, as shown below in figure 1.3

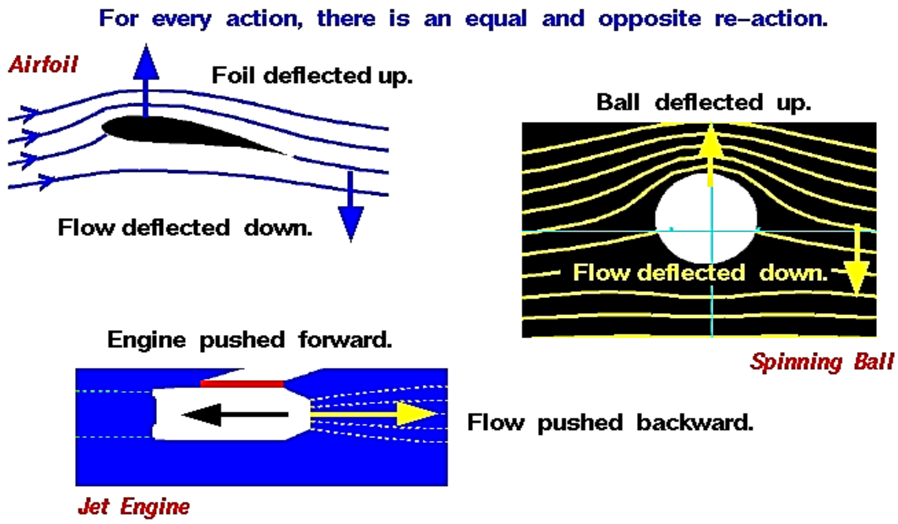

Figure 1.3 Newton's Third Law

- THE BETZ LIMIT

It states that an ideal wind turbine cannot extract more than 59.3% of the kinetic energy, as shown below in the figure 1.4. Betz's law places an upper limit on how much energy can be extracted from moving air. This is called the Power coefficient. Power coefficient, It also predicts that the amount of energy able to be collected from the wind is directly proportional to the collecting area of the rotor disc as well as the cube of the wind speed.

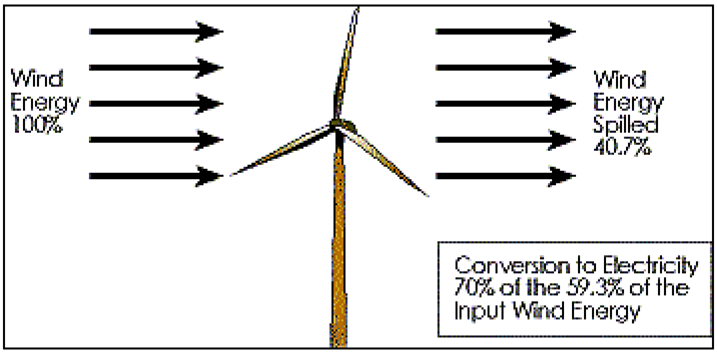

Figure 1.4 The Betz Limit

- BERNOULLI'S PRINCIPLE & LIFT GENERATION

Bernoulli's principle states that when the velocity of the flow increases, such as when it moves over the curved side of the aerofoil blade, then the pressure of the air decreases, as shown below in the figure 1.5. This leads to lifting force on the blade. On the whole rotor scale, the pressure is increased in front of the rotor and decreased behind it resulting in energy extraction. This change in pressure is a feature of reaction turbines.

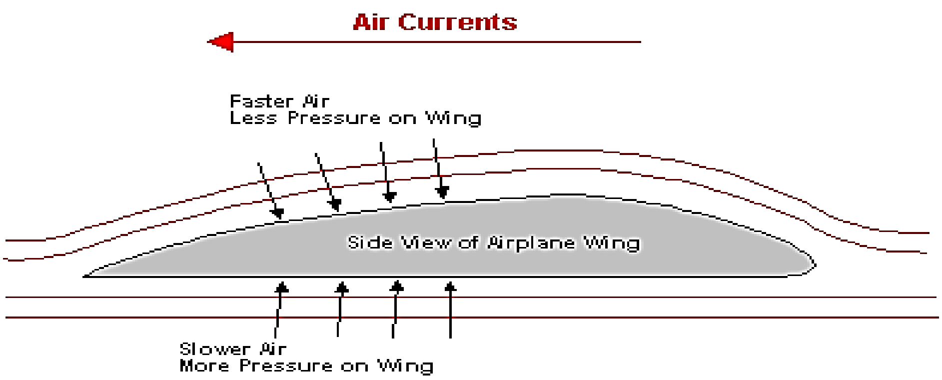

Figure 1.5 Bernoulli's Principle

- AERODYNAMIC FORCE

The force of the wind on a plate is called aerodynamic force. The forces are divided into two components lift and drag. These two components are perpendicular to each other that they make an angle of 90° with each other, as shown below in the figure 1.6[6].

Aerodynamic Force = (Area)* (Pressure)

The pressure from wind can be found using the formula

Pressure from wind = ½ * (Density)*$(wind\ speed)^2$

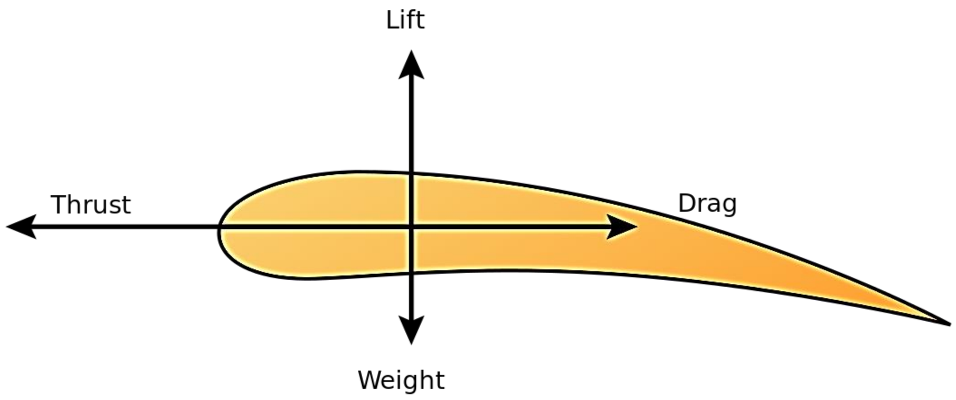

Figure 1.6 Aerodynamic Force

- LIFT AND DRAG

The force component parallel to the direction of the wind is called aerodynamic drag. The drag force is the resistance of air on something that moves in the air or the force from the air when wind flows over an object. The force component perpendicular to the direction of the wind is called the aerodynamic lift. Lift is a force that moves an object to a side (it can be upward). For example, the force that keeps an aeroplane in the air is the lift on its wings. The lift force depends on the angle of attack. When the angle of attack is small the lift force is larger than the drag force. As the angle becomes larger the lift decreases and the drag increases. When the angle of attack is 90°, the lift is zero (for this plate) and the magnitude of drag is maximum. Figure 1.7shows the working of lift and drag.

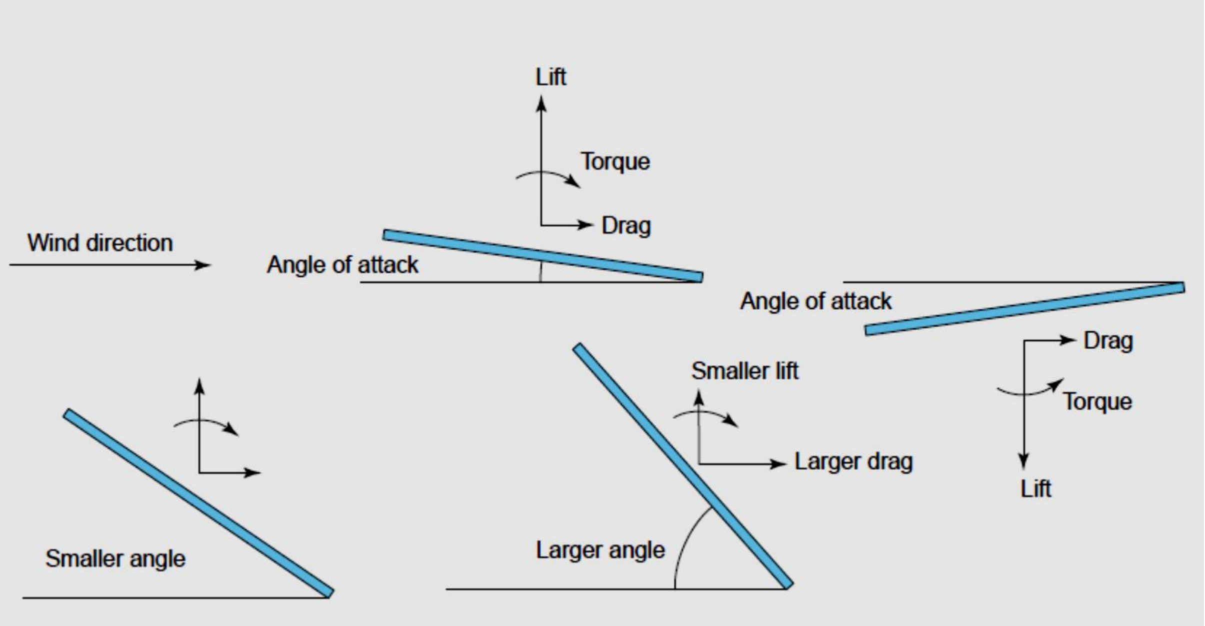

Figure 1.7 Lift and Drag

1.4 OVERVIEW OF WIND TURBINES

Wind turbines can be separated into two basic types determined by which way the turbine spins. Wind turbines that rotate around the horizontal axis are more common, while wind turbines which rotate around the vertical axis are less frequently used. Figure 1.8 shows the general components of a wind turbine[2].

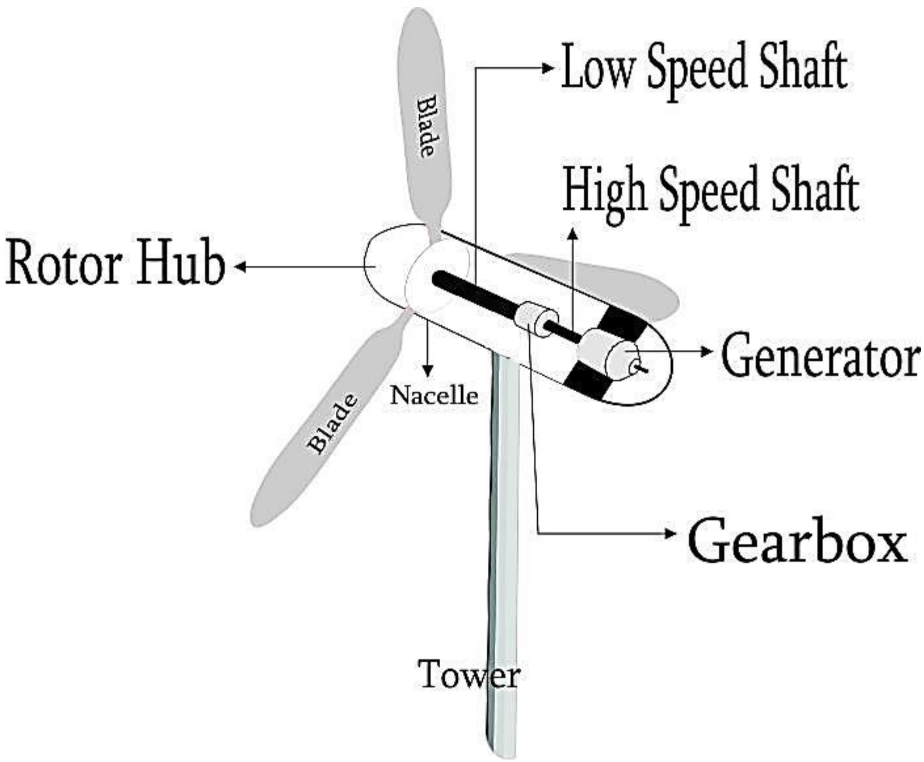

Figure 1.8: **Overview of Wind Turbines**

- HUB

The hub consists of the hub housing and a pitch system. The blade mount of the hub housing is reinforced to enhance structural strength, thereby making the equipment lighter in terms of total weight. The pitch control mechanism is electrically driven to ensure controllability, maintainability, environmental compatibility and other positive characteristics. The system also features three-axis independent control.

- ROTOR BLADES

Rotor blades take the energy out of the wind. They "capture" the wind and convert its motive energy into the rotation of the hub. The profile is similar to that of aeroplane wings. Rotor blades utilize the same "lift" principle: below the wing, the stream of air produces overpressure; above the wing, a vacuum. These forces make the rotor rotate.

- DRIVESHAFT

The drive shaft is based on a single bearing and a short main shaft, resulting in a much lighter weight.

- GEARBOX

Connects the low-speed shaft to the high-speed shaft and increases the rotational speeds from about 30-60 rpm to about 1,000-1,800 rpm; this is the rotational speed required by most generators to produce electricity. The gearbox is a costly (and heavy) part of the wind turbine and engineers are exploring "direct-drive" generators that operate at lower rotational speeds and don't need gearboxes.

- GENERATOR

Produces 60-cycle AC electricity; it is usually an off-the-shelf induction generator.

- HIGH-SPEED SHAFT

This high-speed shaft is the prime mover of the generator.

- NACELLE/HOUSING

Sits atop the tower and contains the gearbox, low- and high-speed shafts, generator, controller, and brake. Some nacelles are large enough for a helicopter to land on.

1.4.1 HORIZONTAL AXIS WIND TURBINES (HAWT)

Horizontal axis wind turbines, also shortened to HAWT, are the commonly used type of Wind turbine. It has blades that look like a propeller that spin on the horizontal axis. Horizontal axis wind turbines have the main rotor shaft and electrical generator at the top of a tower, and they must be pointed into the wind. Small turbines are pointed by a simple wind vane placed square with the rotor (blades), while large turbines generally use a wind sensor coupled with a servo motor to turn the turbine into the wind. Most large wind turbines have a gearbox, which turns the slow rotation of the rotor into a faster rotation that is more suitable to drive an electrical generator.

Since a tower produces turbulence behind it, the turbine is usually pointed upwind of the tower. Wind turbine blades are made stiff to prevent the blades from being pushed into the tower by high winds. Additionally, the blades are placed at a considerable distance in front of the tower and are sometimes tilted up by a small amount. Figure 1.9 shows HAWT.

Figure 1.9 Horizontal Axis Wind Turbines

Downwind machines have been built, despite the problem of turbulence, because they don't need an additional mechanism for keeping them in line with the wind. Additionally, in high winds, the blades can be allowed to bend which reduces their swept area and thus their wind resistance. Since turbulence leads to fatigue failures, and reliability is so important, most HAWTs are upwind machines.

1.4.1.1 DISADVANTAGES OF EXISTING SYSTEM

- Massive tower construction is required to support the heavy blades, gearbox, and generator.
- Components of a horizontal axis wind turbine (gearbox, rotor shaft and brake assembly) being lifted into a position which is difficult
- Downwind variants suffer from fatigue and structural failure caused by turbulence when a blade passes through the tower's wind shadow.
- HAWTs require an additional yaw control mechanism to turn the blades toward the wind. It also requires a braking or yawing device in high winds to stop the turbine from spinning and destroying or damaging itself.
- Cyclic stresses and vibration can quickly fatigue and crack the blade roots, hub and axle of the turbines.

1.4.2 VERTICAL AXIS WIND TURBINE

Vertical axis wind turbines, as shortened to VAWTs, have the main rotor shaft arranged vertically. The main advantage of this arrangement is that the wind turbine does not need to be pointed into the wind. This is an advantage on sites where the wind direction is highly variable or has turbulent winds. Figure 1.10 shows the VAWT

Figure 1.10 Vertical Axis Wind Turbine

With a vertical axis, the generator and other primary components can be placed near the ground, so the tower does not need to support it, also makes maintenance easier. The main drawback of a VAWT generally creates drag when rotating into the wind.

It is difficult to mount vertical-axis turbines on towers, meaning they are often installed nearer to the base on which they rest, such as the ground or a building rooftop. The wind speed is slower at a lower altitude, so less wind energy is available for a given size turbine. Airflow near the ground and other objects can create turbulent flow, which can introduce issues of vibration, including noise and bearing wear which may increase the maintenance or shorten its service life. However, when a turbine is mounted on a rooftop, the building generally redirects wind over the roof and these can double the wind speed at the turbine. If the height of the rooftop mounted turbine tower is approximately 50% of the building height, this is near the optimum for maximum wind energy and minimum wind turbulence[13].

1.4.2.1 ADVANTAGES OF PROPOSED SYSTEM

- No yaw mechanisms are needed.
- A VAWT can be located nearer the ground, making it easier to maintain the moving parts.
- VAWTs have lower wind startup speeds than the typical the HAWTs.
- VAWTs may be built at locations where taller structures are prohibited.
- VAWTs situated close to the ground can take advantage of locations where rooftops, mesas, hilltops, ridgelines, and passes funnel the wind and increase wind velocity.

1.5 CURRENT ENERGY SCENARIO

MONTH WISE POWER SUPPLY POSITION IN TAMILNADU DURING APRIL 2016 TO MARCH 2017

Table 1.1 Month Wise Power Supply Position In Tamilnadu During April 2016 To March 2017

	Apr-16	May-16	Jun-16	Jul-16	Aug-16	Sep-16	Oct-16
Peak Demand (MW)	14822.67	14705.97	14362.44	14517.37	14236.97	14462.6	14435.12
Peak Availability (MW)	14822.67	14668.02	14357.78	14467.48	14158.1	14385.22	14435.12
Surplus(+)/Deficit(-) (MW)	0	-37.9482	-4.65411	-49.8853	-78.869	-77.3826	0
(%)	0.0	-0.3	0.0	-0.3	-0.6	-0.5	0.0

	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17	2016-17
Peak Demand (MW)	13902.44	13319.11	13704.8	13646.71	14249.52	14822.669
Peak Availability (MW)	13893.25	13316.14	13685.1	13639.93	14222.68	14822.669
Surplus(+)/Deficit(-) (MW)	-9.19674	-2.97268	-19.694	-6.78143	-26.847	0
(%)	-0.1	0.0	-0.1	0.0	-0.2	0.0

The total amount of power supplied to Tamil Nadu from April 2016 to March 2017 is given in the above table 5.1

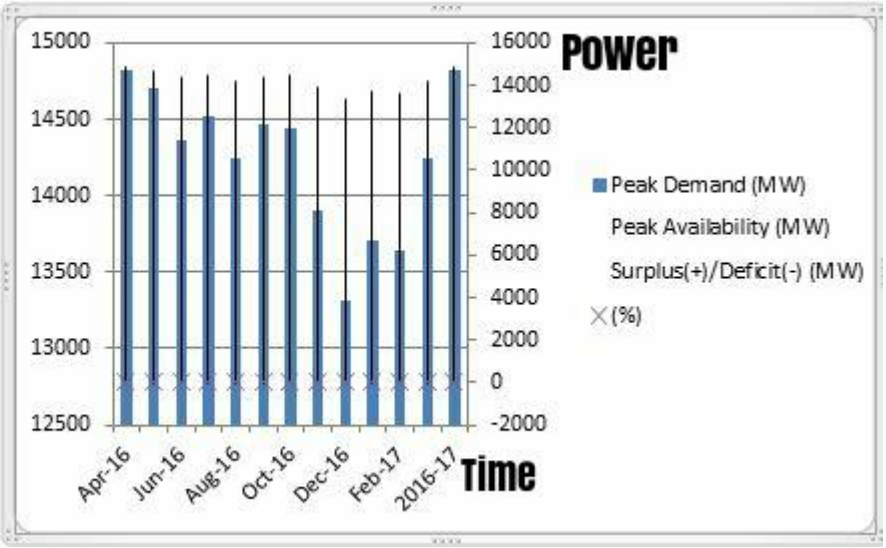

Figure 1.11 **Month Wise Power Supply Position In Tamilnadu During April 2016 To March 2017**[14]

The graphical analysis of the above table is given in the above figure 1.11

PERCENTAGE OF POWER DEMAND MET BY WIND GENERATION

Table 1.2 PERCENTAGE OF POWER DEMAND MET BY WIND GENERATION

Month	Total Wind(MUs)	Energy Met(MUs)	%Energy Met
Oct-16	388.94	23981.95	1.62
Nov-16	412.79	20713.78	1.99
Dec-16	518.99	22346.10	2.32

The total amount of wind energy utilized from October to December in the year 2016 is given in the above table 1.2

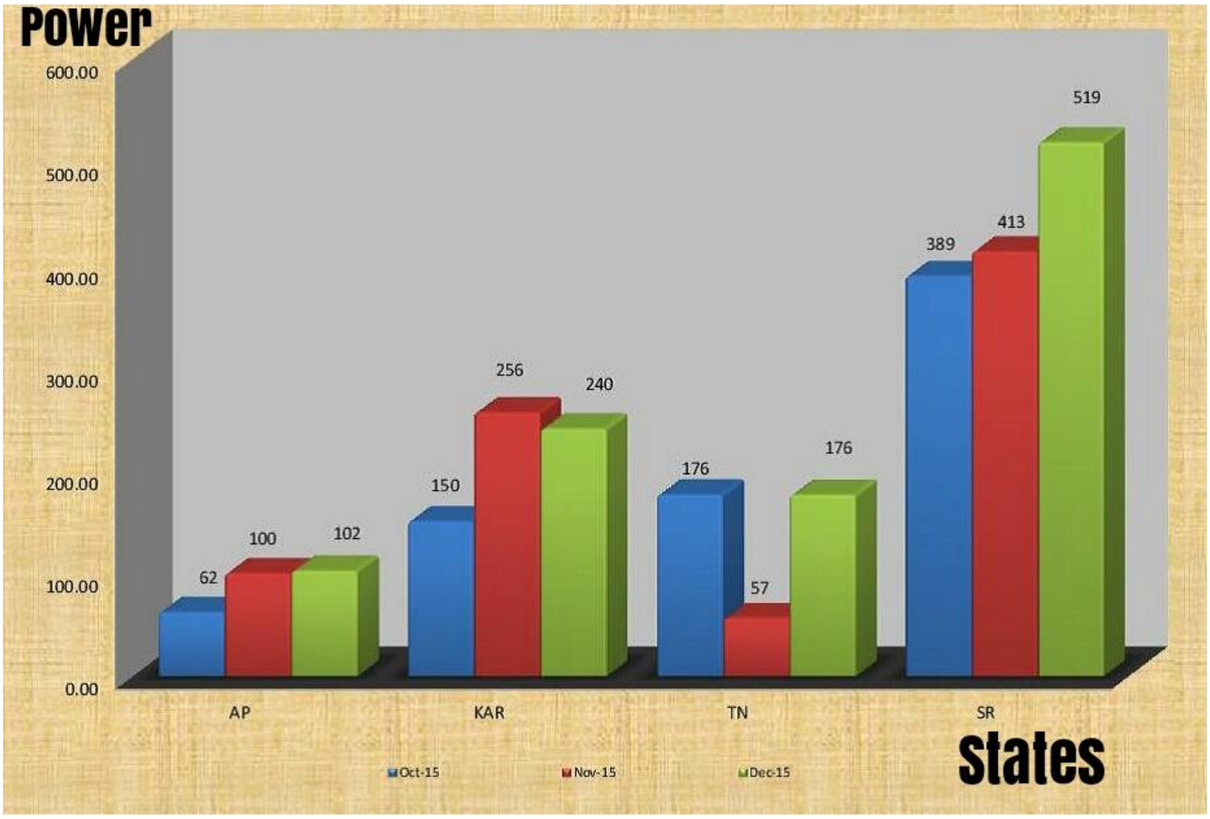

Figure 1.12 PERCENTAGE OF POWER DEMAND MET BY WIND GENERATION IN SOUTH INDIAN STATES IN 2016[15]

The above figure 1.12 shows the total amount of wind energy utilized in South India the form of bar chart.

WIND GENERATION CHARTS (MILLION UNITS VS. DAYS)

The figures 1.13-1.15 below shows the Wind generation in MUs during October, November and December in the year 2016

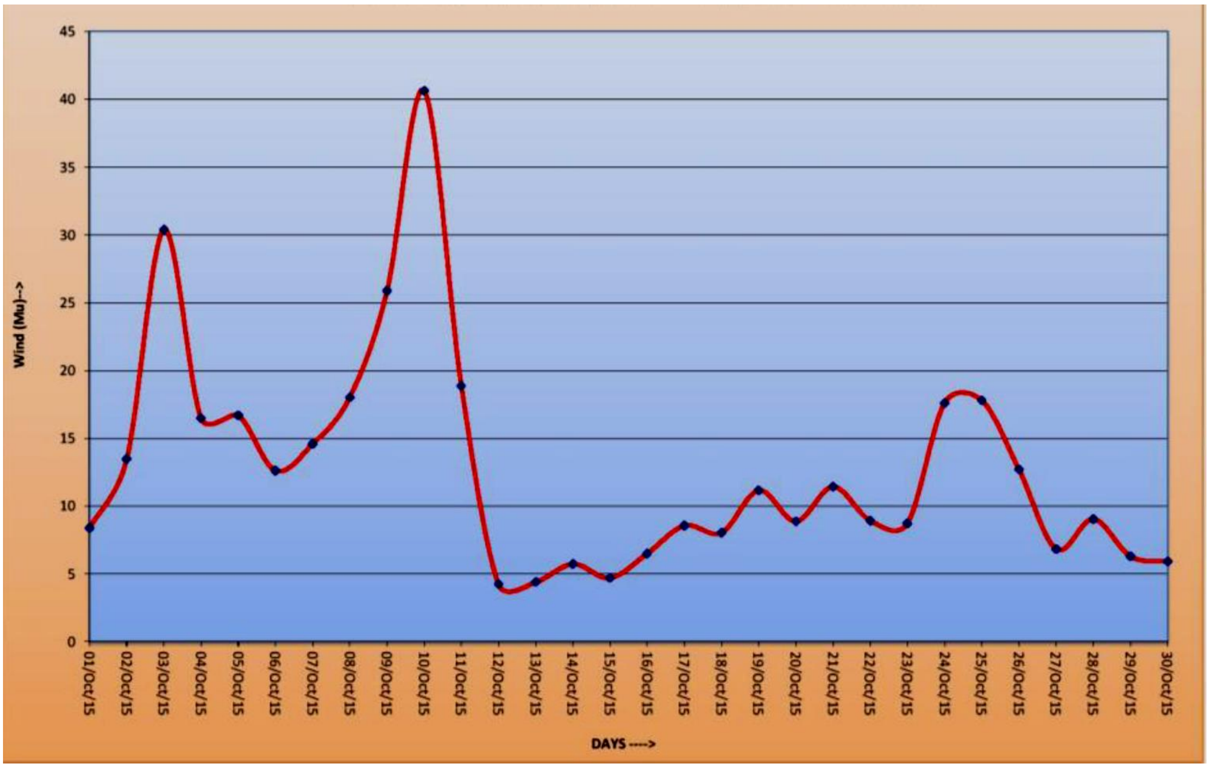

Figure 1.13 Wind generation during October 2017[16]

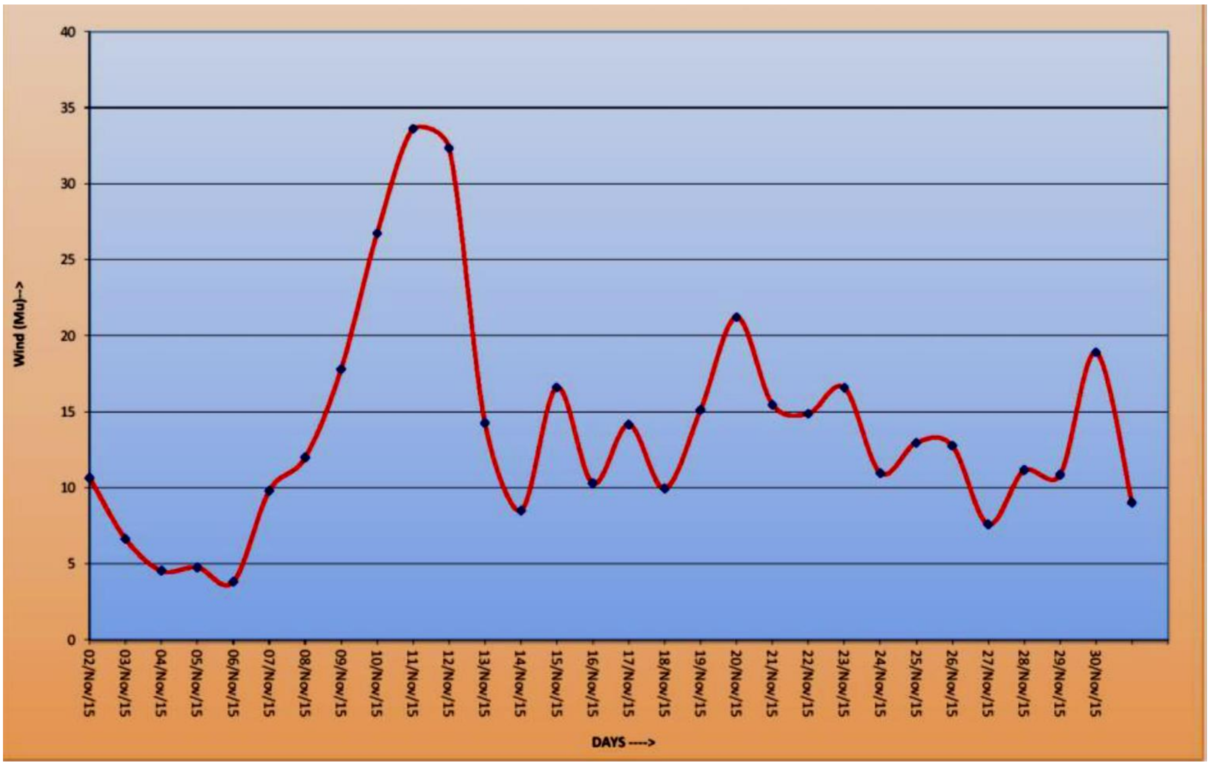

Figure 1.14 Wind generation during November 2017[17]

Figure 1.15 Wind generation during December 2017[18]

MAJOR ENERGY GENERATION

Table1.3 Major Energy Generation In South India During 2016

STATE	THERMAL	HYDRO	GAS/NAPTHA/ DIESEL	WIND	OTHERS	NET SCH (FROM GRID)	DRAWAL (FROM GRID)	AVAILABILITY	DEMAND MET
AP	95.91	9.75	4.59	3.46	11.56	28.83	32.28	154.10	157.55
TELANGANA	48.15	0.00	0.00	0.00	9.69	91.40	93.36	149.24	151.20
KAR	61.12	26.82	4.03	4.52	44.10	65.01	68.11	205.60	208.70
KERALA	0.00	19.97	1.11	0.02	0.13	52.89	55.22	74.12	76.45
TN	108.65	13.31	6.68	2.32	37.63	153.79	154.71	322.38	323.30
PONDY	0.00	0.00	0.00	0.00	0.00	7.50	7.41	7.50	7.41
TOTAL	**313.83**	**69.85**	**16.41**	**10.32**	**103.11**	**399.42**	**411.09**	**912.94**	**924.61**

The power generation in Southern region of Indian depends on four generation methods namely Thermal, Hydro, Gas/Naphtha/Diesel, Wind etc. The above table 1.3, shows the generation methods that compensate for the energy demand in southern India in 01/04/2016.

1.6 ORGANIZATIONAL CHART

CHAPTER 1 deals with the brief introduction about the existing system, literature review and our proposed system.

CHAPTER 2 deals with initial design and development of turbine and generator

CHAPTER 3 deals with the final design and development of turbine and generator.

CHAPTER 4 deals with the results and discussions of the proposed project.

CHAPTER 5 deals with the conclusion and future scope of the project.

CHAPTER 2

INITIAL DEVELOPMENT

2.1 ACRYLIC TURBINE

Poly methyl methacrylate (PMMA), also known as acrylic or acrylic glass is a transparent thermoplastic often used in sheet form as a lightweight or shatter-resistant alternative to glass. The same material can be used as a casting resin, in inks and coatings, and has many other uses. The substance, like many thermoplastics, is often technically classified as a type of glass (in that it is a non-crystalline vitreous substance) hence its occasional historical designation as acrylic glass. Chemically, it is the synthetic polymer of methyl methacrylate.

PMMA is an economical alternative to polycarbonate (PC) when tensile strength, flexural strength, transparency, polishability, and UV tolerance are more important than impact strength, chemical resistance and heat resistance. Additionally, PMMA does not contain the potentially harmful bisphenol-A subunits found in polycarbonate. It is often preferred because of its moderate properties, easy handling and processing, and low cost. Non-modified PMMA behaves in a brittle manner when under load, especially under an impact force, and is more prone to scratching than conventional inorganic glass, but modified PMMA is sometimes able to achieve high scratch and impact resistance.

In this proposed project, Laser cutting is used to form intricate designs from PMMA sheets. PMMA vaporizes to gaseous compounds upon laser cutting, so a very clean cut is made, and cutting is performed very easily. However, the pulsed laser cutting introduces high internal stresses along the cut edge, which on exposure to solvents produce undesirable "stress-crazing" at the cut edge and several millimetres deep. Annealing the PMMA sheet/parts is therefore an obligatory post-processing step when intending to chemically bond laser cut parts together. In the majority of applications, it will not shatter. Rather, it breaks into large dull pieces. Since PMMA is softer and more easily scratched than glass, scratch-resistant coatings are often added to PMMA sheets to protect it (as well as possible other functions).

In the proposed project, despite the fact that acrylic was a low weight option and can rotate in low wind speed, the manufacturing cost is high as it involves repeated cutting, melting and cooling. Also, once melted, it loses its original strength and material becomes uneven in shape. Hence it is unsuitable to be used as a aero leaf material.

2.2 STEEL TURBINE

Steel is an alloy of iron and carbon and other elements. Iron is the base metal of steel. In pure iron, the crystal structure has relatively little resistance to the iron atoms slipping past one another, and so pure iron is quite ductile, or soft and easily formed. In steel, small amounts of carbon, other elements, and inclusions within the iron act as hardening agents that prevent the movement of dislocations that are common in the crystal lattices of iron atoms, thus eliminating the drawbacks of pure iron[12].

The carbon in typical steel alloys may contribute up to 2.14% of its weight. Varying the amount of carbon and many other alloying elements, as well as controlling their chemical and physical makeup in the final steel (either as solute elements, or as precipitated phases), slows the movement of those dislocations that make pure iron ductile, and thus controls and enhances its qualities. These qualities include such things as the hardness, quenching behaviour, need for annealing, tempering behaviour, yield strength, and tensile strength of the resulting steel.

Figure 2.1 Steel turbine

In the proposed project, the steel turbine as shown in the above figure 2.1, was found unsuitable to be used due to one main reason: Weight. The sheer amount of weight it carried needed the tree structure to be more bulky and strong to withstand about 5 such turbines of its like, thus increasing the capital cost. Also, more the turbine weight, more air pressure is needed to make the turbine to rotate; hence they do not work at low wind speed, thus violating one of the project's main objectives. Hence steel is unsuitable to be used as an aero leaf material.

2.3 PLASTIC TURBINE

Plastic is material consisting of any of a wide range of synthetic or semi-synthetic organic compounds that are malleable and so can be moulded into solid objects. Plasticity is the general property of all materials which can deform irreversibly without breaking but, in the class of mouldable polymers, this occurs to such a degree that their actual name derives from this specific ability. Plastics are typically organic polymers of high molecular mass and often contain other substances. They are usually synthetic, most commonly derived from petrochemicals, however, an array of variants are made from renewable materials such as polylactic acid from corn or cellulosics from cotton linters.

Due to their ease of manufacture, versatility, and imperviousness to water, plastic is used in a multitude of products of different scale, including paper clips and spacecraft. They have prevailed over traditional materials, such as wood, stone, horn and bone, leather, metal, glass, and ceramic, in some products previously left to natural materials[11].

In developed economies, about a third of plastic is used in packaging and roughly the same in buildings in applications such as piping, plumbing or vinyl siding. Other uses include automobiles (up to 20% plastic), furniture, and toys. In the developing world, the applications of plastic may differ — 42% of India's consumption is used in packaging.

Plastics have many uses in the medical field as well, with the introduction of polymer implants and other medical devices derived at least partially from plastic. The field of plastic surgery is not named for use of plastic materials, but rather the meaning of the word plasticity, with regard to the reshaping of flesh.

In this proposed project, even though plastic is said to be lightweight and rotates at low wind speed; it is typically costly to buy a plastic sheet and shape it by 3D printing, which increases the making cost undesirably high. Hence plastic as an alternative to making an aero leaf is eliminated.

2.4 ALUMINIUM TURBINE

Aluminium is remarkable for its low density and its ability to resist corrosion through the phenomenon of passivation. Aluminium and its alloys are vital to the aerospace industry and important in transportation and building industries, such as building facades and window frames. The oxides and sulphates are the most useful compounds of aluminium.

Aluminium is the most widely used non-ferrous metal. Aluminium is almost always alloyed, which markedly improves its mechanical properties, especially when tempered. It is used as pure metal only when corrosion resistance and/or workability are more important than strength or hardness. The main alloying agents are copper, zinc, magnesium, manganese, and silicon (e.g., duralumin) with the levels of other metals in a few per cent by weight[10].

Corrosion resistance can be excellent because a thin surface layer of aluminium oxide forms when the bare metal is exposed to air, effectively preventing further oxidation. The strongest aluminium alloys are less corrosion resistant due to galvanic reactions with alloyed copper. This corrosion resistance is greatly reduced by aqueous salts, particularly in the presence of dissimilar metals.

Some of the many uses for aluminium metal are in: Transportation as sheet, tube, and castings, Packaging, Food and beverage containers, Construction, A wide range of household items, Street lighting poles, Outer shells and cases for consumer electronics and photographic equipment and as Electrical transmission lines for power distribution.

Figure 2.2 Aluminium Turbine

In the proposed project, turbine made of aluminium as shown in the above figure 2.2, is found to be strong, light weight, easy to make and easy to assemble. Also these factors contributed to the fulfilment of the objectives; hence aluminium was chosen to make aero leaves.

2.5 AXIAL FLUX PM GENERATOR

Another consideration for the generator type was whether to build a radial flux, or axial flux PMG. The radial flux would have required many concentric cylindrical parts, a cylindrical casing, cylindrical magnets, rotor etc. In an axial flux generator, the rotor is a flat disk of magnets which rotates on a shaft above a flat ring of stator coils. In analysing the two design types, an axial flux PMG was chosen as our final design choice for reasons of simplicity, ease of manufacturing and cost of materials[3].

- PRINCIPLE:

In an axial flux PMG, there is a rotor mounted with a ring of magnets. These magnets are attached over an iron disc with a pole pitch of 30 degrees.

The rotor is connected to the generator shaft which is driven, in this case, by the savonius turbine. The magnets on the rotor are arranged so that alternating north and south poles are perpendicular to the rotors flat top and bottom faces. The rotation of the rotor causes an alternating magnetic field at a given point above the rotor. The alternating magnetic field from the rotor induces a voltage in the coils of the stator. Higher the number of turns in the coils, higher will be the voltage induced. Also, the closer the magnets are to the coils, the higher the voltage that will be induced. Magnetic flux density drops off with the square of the distance, so it is important to reduce the air gap between stator and rotor for better efficiency.

And finally, the faster the rotor spins, the faster the magnetic fields are switched, the higher the voltage that will be induced. Voltage is a function of speed, while current is a function of torque. Higher the torque, higher the current that is produced. The lower the resistance, the higher the current and torque that will be produced. Efficiency is affected by the weight of the rotor and shaft, as well as the resistive losses in the copper coils, the frictional losses in the bearings and the viscous drag losses from rotating in water. These are the basics of axial flux PMG operation

- MAGNET SELECTION:

In an early stage of the design, two types of magnet configurations were considered, a traditional array with north and south poles alternating each magnet in the ring, or a Halbach Array. The Halbach Array is a configuration of magnets that restricts most of the magnetic field to one side of the ring, which would improve the efficiency of the generator. However, it is achieved by arranging the magnets in a fashion so that the north and south poles are no longer in contact with each other, meaning there would be a lot of magnetic resistance to get the ring to remain aligned. Because of the difficulty to assemble, as well as being more challenging to source magnets to meet the needs of the design, our design utilized a traditional magnet array[4].

Magnet selection was a very important step in the design of our generator. The magnets were the most expensive, and difficult to customize part of the design. Because of the importance of magnetic field strength, rare earth magnets, samarium-cobalt and neodymium-iron-boron, were most appropriate. In this proposed project, we have chosen 12 neodymium magnets. The magnets we chose to use were 1.5” thick, 4.5 cm long and 2 cm broad[9]. The thicker the magnets, the stronger the magnetic field density would be at the coils.

Figure 2.3 Magnet arrangement

- COIL SELECTION:

The coil used is a 16 gauge copper coil. Voltage induced is a function of the number of turns per coil, and the number of phases produced based on the 6 magnet ring configuration depends on the number of coils. These two considerations were kept in mind when deciding on the coil configuration for the stator. The magnets and coils are arranged in a way so that the north side of magnet passes over the leading edge of every coil. This way the 6 magnets and 6 coils produce 3 phases. 3 phases are tied together in a y- configuration so that one side of each coil is tied to a neutral point at the centre of the stator ring, while the other sides of each of the 6 coils containing the same phase are tied together. By having multiple coils with the same phase, the resistance due to the copper windings is reduced by combining the coil resistances in parallel. This also reduces the current in each coil, which will, in turn, reduce the heat losses. The y-configuration used to tie the coils together also provided higher voltage and lower current for the same power rating compared to a delta connection.

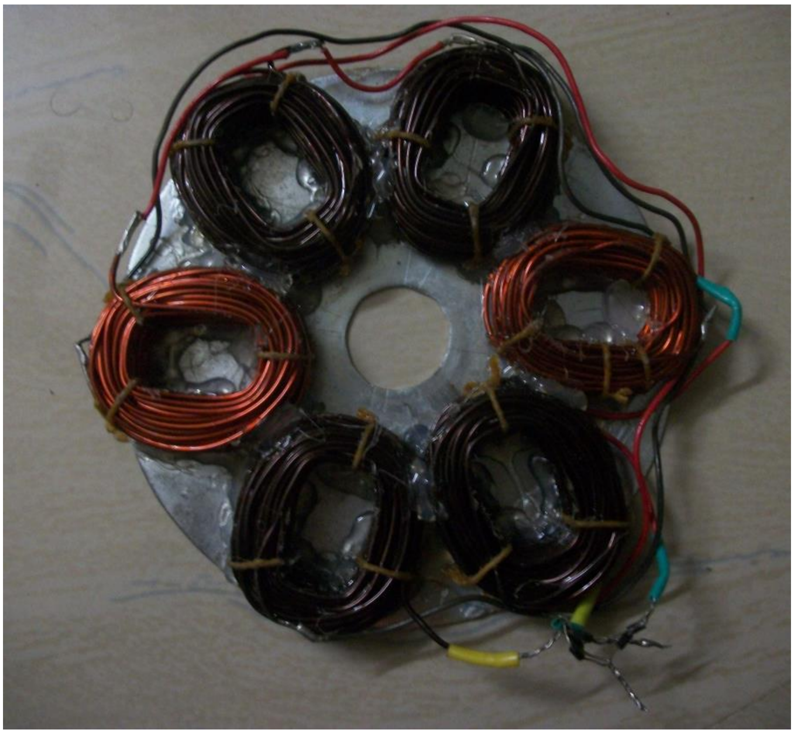

Figure 2.6 Coil arrangement

- WORKING:

When the wind hits the turbine, the rotor starts to rotate. When this happens, varying magnetic field is produced by the magnets. By the principle of electromagnetic induction, EMF is induced in the stator coils. This EMF is alternating in nature. This can be rectified into DC by using bridge rectifiers and is used to charge the battery.

- DISADVANTAGES OF IRON DISC:

The force of attraction between iron plate and permanent magnets hinder the rotating speed of the rotor, thus reducing the mechanical power of the turbine. Due to this, the electrical power generated also reduces. This decreases the overall efficiency of the axial flux generator.

Hence, we then tried using an acrylic disc to house the coils in the same manner as it was done using the iron disc.

- DISADVANTAGES OF ACRYLIC DISC:

When analysed, the output voltage got was very less than the voltage required to charge the battery. This is because in an iron disc, the flux is produced in a closed loop form, which increases the overall induced EMF. This advantage is not obtained in case of an acrylic disc. Thus the amount of EMF produced is low, hence decreasing the overall efficiency.

Hence, the idea of using an axial flux permanent magnet generator was dropped.

CHAPTER 3

FINAL DESIGN AND DEVELOPMENT

3.1 TREE STRUCTURE

The main stem of the wind tree is made up of a 7 foot, 1.5 inch, stainless steel rod. The stainless steel material is chosen as it is naturally strong and can withstand against extreme weather conditions.

The tree branches are made up of mild steel flat rods of length 300 mm. 2 pairs of branches are fixed to the stem at same levels while the remaining one is fixed independently. At the tip of each branch, a cylindrical section is used to hold on the aero leaf to the branch solidly. The length of the branches is based on the fact that there should be smooth flow of air between each aero leaf without any obstruction between them.

The solar panel is kept on top of the stem. It’s inclined towards the direction and angle at which the sun’s ray’s fall onto the particular geographical location. The panel can be easily adjusted using screws and fixed sturdily.

The wires from the leaves and the panel are passed through the insides of the stem and into the kit box containing the charge controller, battery and the inverter. This kit box is then hooked to the bottom part of the stem. An additional feature of the kit box is that it is water proof and temperature resistant; making it suitable against extreme weather conditions.

The tree structure for the proposed project is shown in the next figure 3.1

Figure 3.1 Tree structure

3.2 TURBINE DESIGN

Power from wind can be extracted using a horizontal or vertical axis turbine. Vertical axis turbines are capable of extracting power from wind regardless of the direction of flow. Also, vertical axis turbines operate in turbulent air patterns better than horizontal designs. Due to its simple and low cost construction, acceptance of air from any direction, high starting torque, low operating speed and less maintenance; Savonius rotor is hence used in this proposed project.

3.2.1 CONSTRUCTION AND WORKING OF SAVONIUS TURBINE:

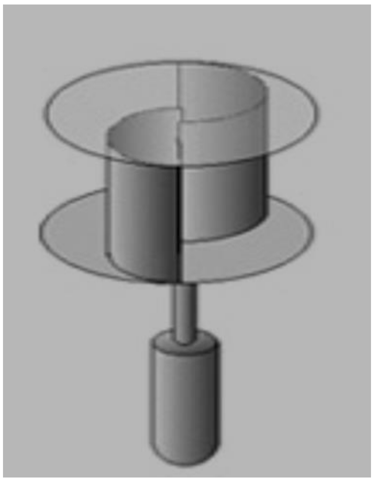

Figure 3.2 Savonius turbine

Savonius rotor is made by cutting the Flettner cylinder into two halves along the central plane and then moving the two semi cylindrical surfaces sideways along the cutting plane so that the cross section resembled the letter "S", as shown in the above figure 3.2.

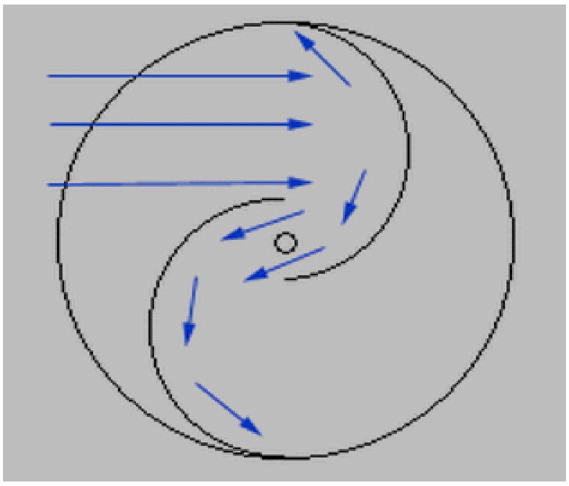

Figure 3.3 Air flow in Savonius turbine

Savonius turbine relies on stagnation principles to convert wind into rotational energy. The Savonius rotor uses stagnation pressure on one side to promote rotation around a central vertical axis. The blade turning redirects wind around itself with its rounded shape. Any tangential flow of wind will produce a positive force on the rotor. A Savonius design relies on the pressure of the wind against the rotor blade to create torque. As such, a Savonius design cannot exceed the speed of air and operates at a lower RPM range than would a horizontal axis turbine[7]. The air flow inside a savonius turbine is shown in above figure 3.3.

3.2.2 ADVANTAGES OF 2 BLADE SYSTEM OVER 3 BLADE SYSTEM:

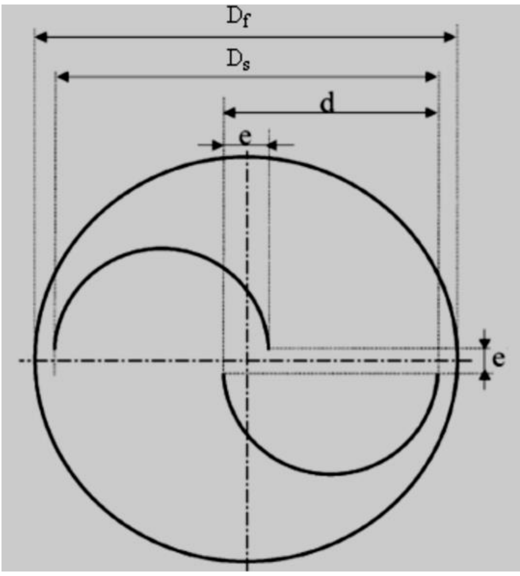

Figure 3.4 Design specification of Savonius turbine

In this proposed project, a 2 blade system savonius turbine as shown in above figure 3.4; is used over 3 blade system. The main advantages of 2 blade system over the other are:

- Rotor weight of 3 blade system is higher and the rotational speed at which peak power would be delivered would drop. That, in turn, would increase the rotor torque — necessitating a thicker shaft — and the slower speed would mean a more expensive gearbox, as the gear ratio would increase. 2 blade system may only be about 13% lighter than 3 blade, hence there is an ease of handling and assembling the turbine.

- Less wind power is enough to run the 2 blade system

- Drag force is less on the turbine.

3.2.3 DESIGN EQUATIONS:

- ASPECT RATIO:
  The aspect ratio (A_α) represents the height (H_s) of the rotor relatively to its diameter (D_S). This is also an important criterion for the performances of a Savonius rotor[5]:
  $$\mathbf{A_{\alpha}} = \frac{\mathbf{Hs}}{\mathbf{Ds}} \qquad \textbf{.....(1)}$$
  Generally, a value of Aα is selected larger than 1 to improve the efficiency

- OUTPUT POWER:
  If CPs is the power coefficient of a Savonius turbine then the power (P) can be obtained from water is,
  $$\boldsymbol{P = 0.5 * C_{Ps} * A_s * \rho * V^3} \qquad \textbf{....(2)}$$
  Where,
  P is the output power (W)
  ρ is the density of water (kg/m3)
  As= (Height ×Diameter) = (Hs×Ds), is the swept area (m^2) of Savonius rotor
  V is the speed of water (m/s)

The Aero leaf made for the proposed project is shown in below figure:

Figure 3.5 Aero leaf

3.3 SOLAR MODULE

3.3.1 SOLAR PANEL

Solar panel refers either to a photovoltaic module, a solar hot water panel, or to a set of solar photovoltaic (PV) modules electrically connected and mounted on a supporting structure. A PV module is a packaged, connected assembly of solar cells. Solar panel can be used as a component of a larger photovoltaic system to generate and supply electricity in commercial and residential applications each module is rated by its dc output power under standard test conditions (STC), and typically ranges from 100 to 320 watts.

Figure 3.6 Solar panel

The efficiency of a module determines the area of a module given the same rated output-an 8% efficient 230 watt module will have twice the area of a 16% efficient 230 watt module. There are few solar panels available that are exceeding 19% efficiency. A single solar module can produce only a limited amount of power, most installations contain multiple modules.

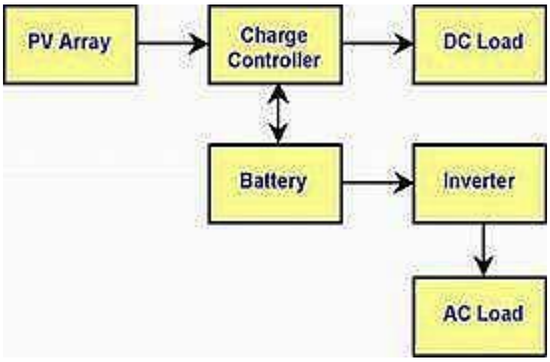

Figure 3.7 Block diagram of solar energy system

A photovoltaic system typically includes a panel or an array of solar modules, an inverter. It may include even one or more batteries, to store the energy and use when there is no sufficient solar power. A solar tracker may also be implemented to increase the efficiency of the whole system.

3.3.2 PHOTOVOLTAIC THEORY:

Photovoltaic (PV) is a method of converting solar energy into direct current electricity using semiconducting materials that exhibit the photovoltaic effect. A photovoltaic system employs solar panels composed of a number of solar cells to supply usable solar power. Power generation from solar PV has long been seen as a clean sustainable energy technology which draws upon the planet's most plentiful and widely distributed renewable energy source-the sun.

The direct conversion of sunlight to electricity occurs without any moving parts or environmental emissions during operation. The phenomenon behind this is the photovoltaic theory.

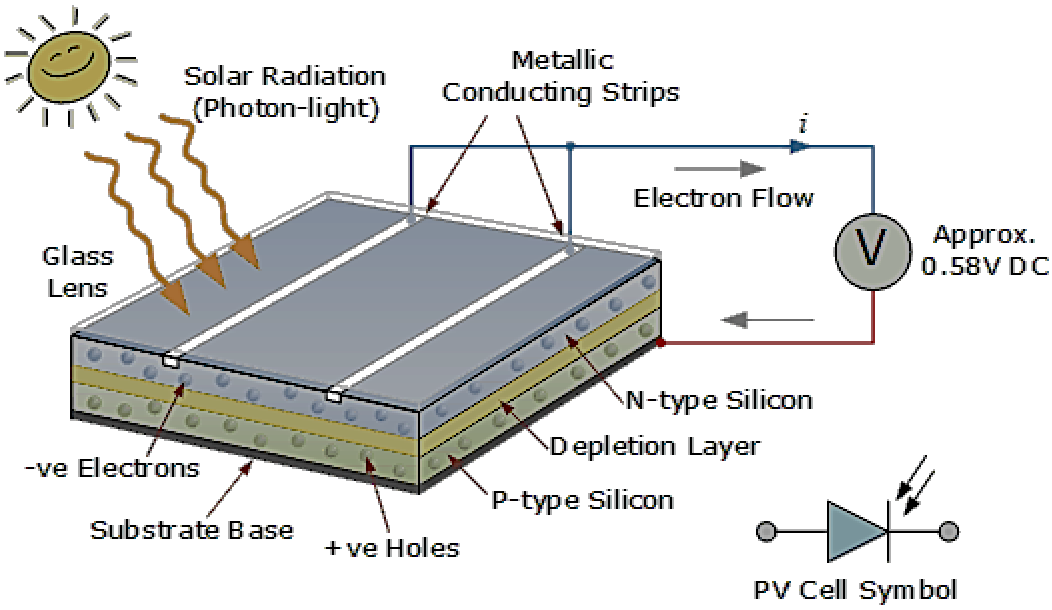

Figure 3.8 Working of Solar cell

The theory briefly states that when a material (such as germanium, silicon, etc.) is irradiated by a beam of photons there is an excitation of the molecules present in the material, thus giving rise to production of electrical energy (Fig 3.8) .Other materials that are used for photovoltaic include mono crystalline silicon, polycrystalline silicon, amorphous silicon, cadmium telluride and copper indium gallium selenide/sulphide. Copper solar cables connect modules (module cable), arrays (array cable), and sub-fields. Because of the growing demand for renewable energy sources, the manufacturing of solar cells and photovoltaic arrays has advanced considerably in recent years.

3.4 DC GENERATOR

A DC generator is an electrical generator that produces direct current with the use of a commutator. DC generators were the first electrical generators capable of delivering power for industry, and the foundation upon which many other later electric-power conversion devices were based, including the electric motor, the alternating-current alternator, and the rotary converter.

The electric DC generator uses rotating coils of wire and magnetic fields to convert mechanical rotation into direct electric current through Faraday's law of induction. A DC generator machine consists of a stationary structure, called the stator, which provides a constant magnetic field, and a set of rotating windings called the armature which turn within that field. Due to Faraday's law of induction the motion of the wire within the magnetic field creates an electromotive force which pushes on the electrons in the metal, creating an electric current in the wire.

The commutator is needed to produce direct current. When a loop of wire rotates in a magnetic field, the magnetic flux through it, and thus the potential induced in it, reverses with each half turn, generating an alternating current. The commutator is essentially a rotary switch. It consists of a set of contacts mounted on the machine's shaft, combined with graphite-block stationary contacts, called "brushes”. The commutator reverses the connection of the windings to the external circuit when the potential reverses, so instead of alternating current, a pulsing direct current is produced.

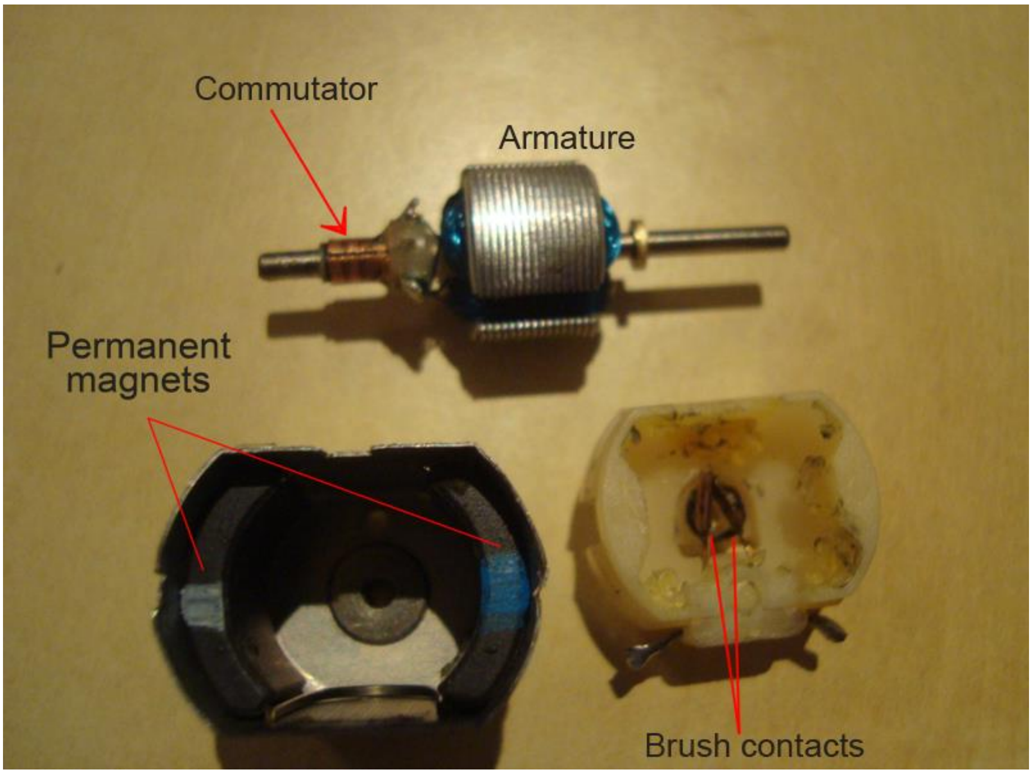

Figure 3.9 Parts of DC Generator

In the DC generator, permanent magnets (located in stator) provide magnetic field, instead of stator winding. The stator is usually made from steel in cylindrical form. Permanent magnets are usually made from rare earth materials or neodymium. The rotor is slotted armature which carries armature winding. Rotor is made from layers of laminated silicon steel to reduce eddy current losses. Ends of armature winding are connected to commutator segments on which the brushes rest. Commutator is made from copper and brushes are usually made from carbon or graphite. When the rotor is rotated, the rotor windings gets induces alternating EMF. The commutator then converts it into direct current and charges the battery. The parts of the DC generator can be seen in the above figure 3.9

DC generators still have some uses in low power applications, particularly where low voltage DC is required, since an alternator with a semiconductor rectifier can be inefficient in these applications. Hand cranked DC generators are used in clockwork radios, hand powered flashlights, mobile phone rechargers, and other human powered equipment to recharge batteries.

3.5 CHARGE CONTROLLER

A charge controller is a device used to limit the rate at which electric current is added to or drawn from electric batteries. It prevents overcharging and may protect against overvoltage, which can reduce battery performance, lifespan and may pose a safety risk. It may also prevent deep discharging a battery, or perform controlled discharges, depending on the battery technology, to protect battery life.

They are of 2 types- Series and Shunt charge controllers. A series charge controller or series regulator disables further current flow into batteries when they are full. A shunt charge controller or shunt regulator diverts excess electricity to an auxiliary or "shunt" load, such as an electric water heater, when batteries are full.

Simple charge controllers stop charging a battery when they exceed a set high voltage level, and re-enable charging when battery voltage drops back below that level. Charge controllers may also monitor battery temperature to prevent overheating. Some charge controller systems also display data, transmit data to remote displays, and data logging to track electric flow over time.

Circuitry that functions as a charge regulator controller may consist of several electrical components, or may be encapsulated in a single microchip, an integrated circuit (IC) usually called a charge controller IC or charge control IC.

Charge controller circuits are used for rechargeable electronic devices such as cell phones, laptop computers, portable audio players, and uninterruptible power supplies, as well as for larger battery systems found in electric vehicles and orbiting space satellites.

The charge controller used for the proposed project is given in below figure 3.10.

Figure 3.10 Charge controller

3.6 BATTERY

An electric battery is a device consisting of one or more electrochemical cells with external connections provided to power electrical devices. When a battery is supplying electric power, its positive terminal is the cathode and its negative terminal is the anode. Batteries contain electrolyte, which is a substance that produces an electrically conducting solution when dissolved in a polar solvent, such as water. When a battery is connected to an external circuit, electrolytes are able to move as ions within, allowing the chemical reactions to be completed at the separate terminals and so deliver energy to the external circuit. It is the movement of those ions within the battery which allows current to flow out of the battery to perform work.

They are of 2 types- Primary and secondary. Primary batteries are used once and discarded; the electrode materials are irreversibly changed during discharge. Common examples are the alkaline battery used for flashlights and a multitude of portable electronic devices. Secondary batteries can be discharged and recharged multiple times using an applied electric current; the original composition of the electrodes can be restored by reverse current. Examples include the lead-acid batteries used in vehicles and lithium-ion batteries used for portable electronics such as laptops and smartphones.

Batteries come in many shapes and sizes, from miniature cells used to power hearing aids and wristwatches to small, thin cells used in smartphones, to large lead acid batteries used in cars and trucks, and at the largest extreme, huge battery banks the size of rooms that provide standby or emergency power for telephone exchanges and computer data centres.

Figure 3.11 Battery

In this proposed project, the battery used is a 12V, 7 Ah, sealed-maintenance free (SMF) valve regulated lead acid (VRLA) battery as shown in above figure 3.11. It works on oxygen gas recombination principle: when the battery is charged, the oxygen evolved from the positive plate is made to recombine with negative plates. Due to this, the battery does not lose any electrolyte and therefore does not require any top-up during its lifetime. This battery use plates with optimum thickness to deliver the high discharge performances desired for the UPS requirements. The unique grind alloy used in this battery makes it suitable for better cycle life. This also has low self-discharge and is highly efficient[1].

3.7 INVERTER

A power inverter, or inverter, is an electronic device or circuitry that changes direct current (DC) to alternating current (AC). The input voltage, output voltage and frequency, and overall power handling depend on the design of the specific device or circuitry. The inverter does not produce any power; the power is provided by the DC source. A power inverter can be entirely electronic or may be a combination of mechanical effects (such as a rotary apparatus) and electronic circuitry.

A typical power inverter device or circuit requires a relatively stable DC power source capable of supplying enough current for the intended power demands of the system. The input voltage depends on the design and purpose of the inverter. In this proposed project, a 12V DC inverter is used.

An inverter can produce a square wave, modified sine wave, pulsed sine wave, pulse width modulated wave (PWM) or sine wave depending on circuit design. In this proposed project, a sine wave inverter is used.

A power inverter device which produces a multiple step sinusoidal AC waveform is referred to as a sine wave inverter. Where power inverter devices substitute for standard line power, a sine wave output is desirable because many electrical products are engineered to work best with a sine wave AC power source. The standard electric utility provides a sine wave, typically with minor imperfections but sometimes with significant distortion.

Sine wave inverters with more than three steps in the wave output are more complex and have significantly higher cost than a modified sine wave, with only three steps, or square wave (one step) types of the same power handling. Switch-mode power supply (SMPS) devices, such as personal computers or DVD players, function on quality modified sine wave power. AC motors directly operated on non-sinusoidal power may produce extra heat, may have different speed-torque characteristics, or may produce more audible noise than when running on sinusoidal power.

The AC output frequency of a power inverter device is usually the same as standard power line frequency, 50 or 60 hertz. The AC output voltage of a power inverter is often regulated to be the same as the load voltage, typically around 220 V. A power inverter will often have an overall power rating expressed in watts.

3.8 WORKING MODEL AND OPERATION

3.8.1 OVERALL BLOCK DIAGRAM:

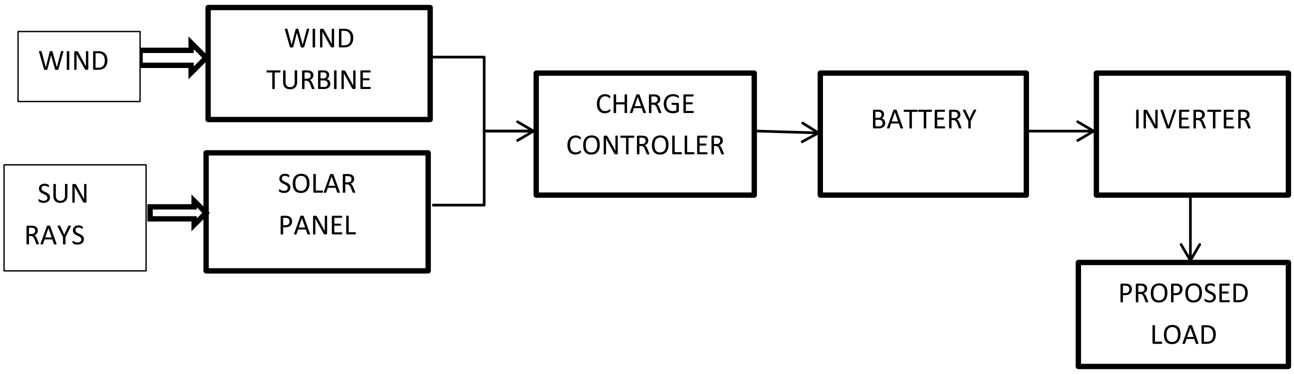

Figure 3.12 Overall Block diagram

3.8.2 WORKING:

In this concept, wind energy is used to generate electricity with the help of Aero leaves. These Aero leaves are made of aluminium, which is cut and assembled into a specified shape based on the requirement. Here we are using a radial flux generator (dynamo) which will be equal to the number of Aero leaves. This model mainly works on the principle of "Faradays law of electromagnetic induction", which states that "Whenever a conductor is placed in a varying magnetic field (Or conductor is moved in a magnetic field) an EMF gets induced in the conductor".

Aero leaves starts to rotate with minimum speed of 7Kmph when air flows through it. As Aero leaves are directly coupled to the generator, mechanical energy gets converted into electrical energy because of the fact that the generator consists of armature (magnet) and the field coil. An EMF is induced due to the relative motion between the rotating armature and magnetic field due to field coil.

Each aero leaf along with generators are connected in parallel, so the generated current will get added. This resulting DC output is given to the charge controller, which prevents the overcharging of the battery. The output power is then stored in a battery. Power from the battery is then used to drive the load.

CHAPTER 4

RESULTS AND DISCUSSIONS

Figure 4.1 Final product

4.1 RESULTS

The output power from the wind tree as shown in above figure 4.1 was calculated for a week. This was done by calculating the voltage for every 2 hours over the past 7 days using a data logger. The average power during each time interval was calculated and a graph analysis between voltage (V) and time period (T) is shown in below figure 4.2:

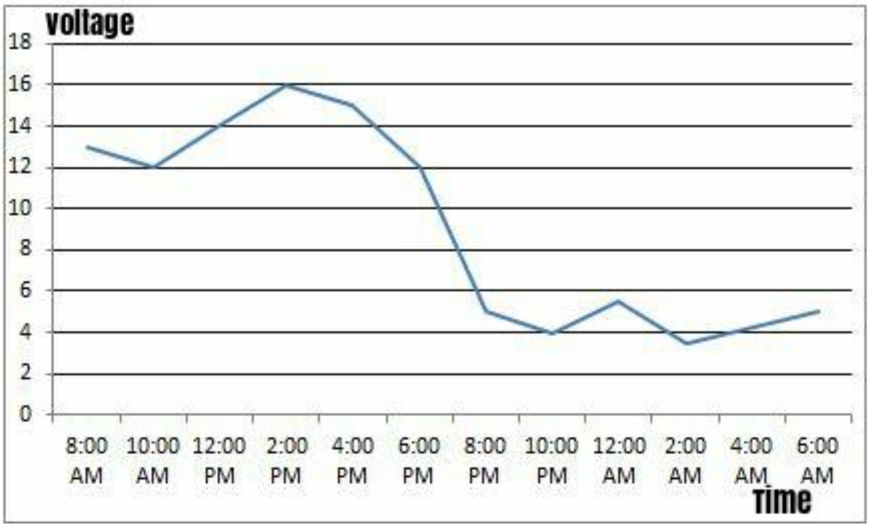

Figure 4.2 Result

4.2 DISCUSSIONS

During early morning, there is a pretty good combination of wind and solar energy. Hence the output is also pretty high, touching from 11V to 14V. In the afternoon, there is a huge abundance of solar energy; hence the output voltage is also very high, reaching up to 16V peak power. As evening arrives, both the solar and wind energy drops together and the output can reach up to 5V at 6pm and 4 V at 10pm. During midnight, wind energy is found to be decently present, reaching up to 6V at maximum. When dawn arrives at 4am, the solar energy starts to contribute to output power and hence the output power starts growing slowly. Hence this cycle continues in this same power average.

On comparing the conventional windmill with the wind tree, it is found that the wind tree continuously supplies power throughout without reaching zero, as compared with the conventional windmill. Also, wind tree depends on solar energy too; it is more robust, has less capital cost, requires less maintenance and can be assembled easily as compared to a conventional wind turbine.

CHAPTER 5

CONCLUSION AND FUTURE SCOPE

5.1 CONCLUSION

The main objective of the project has been presented and the wind tree that has been successfully implemented can generate electric power using Aero leaves and a solar panel to power lighting devices. Due to the increasing demand of clean energy, these kinds of energy sources improve the concept of power generation. Wind energy is the best source of renewable energy and can become an important asset to solve climate change and global warming issues in the future.

5.2 FUTURE SCOPES

- In this proposed project, the solar panel is fixed rigidly in a particular angle to receive the solar energy. By using a panel which moves accordingly to the sun's direction, we can obtain maximum efficiency for the solar panel. This technology is still in research process.

- During highly extreme weather conditions, the high wind speed can damage or either break the Aero leaf. In order to avoid this condition, a mechanical brake can be used to stop the motion of the leaf.

- By fixing a flexible solar panel made of nanomaterial over the turbine itself, solar energy can be harnessed along with wind energy without appreciable rise in temperature of the panel.

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APPENDIX

(1) $A_\alpha = \frac{Hs}{Ds}$

= 280mm / 140mm

= **2**

(2) $P = 0.5 * C_{Ps} * A_s * \rho * V^3$

= 0.5 * 0.7932* (0.14 * 0.28) * 1 * (5^3)

= **2W** (approx.)