HYBRID POWER GENERATION BY SOLAR TRACKING AND VERTICAL AXIS WIND TURBINE (DESIGN AND ANALYSIS)

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Abstract *- The main objective of this project is "Hybrid Power Generation by Solar Tracking and Vertical Axis Wind Turbine" wherein, design of the components and their analysis has been carried out and, the fabrication of the model has been done as per the calculations that have been obtained from the design and analysis.*

Electricity has helped in reducing physical efforts to a very large extent, but, the way in which it is produced is quite a matter of concern. Even today, most of the electricity that we use is produced through conventional methods. These conventional methods commonly use fossil fuels to produce electricity. Not only are these methods expensive, but also cause grave damage to the environment. The use of fuels for the generation of electricity results in increased costs and emissions of hazardous pollutants. The only alternative is a new method that is not only cheap and efficient, but also eco-friendly.

The Solar Tracking - Vertical Axis Wind Turbine System is capable of satisfying both these requirements. In addition to being eco-friendly, it is also relatively cheaper when compared to the conventional methods of electricity generation. This turbine uses both Solar and Wind Energies to generate electricity. So, we have two efficient and inexhaustible sources for uninterrupted generation of electricity. The system has two basic components – one for generation of electricity through Solar Energy and another one for generation from Wind Energy. Even in the case of absence of either of the two sources, the other remaining source could be used to supplement the absence of the former. Due to all these features, the Solar-Vertical Axis Wind Turbines could be considered suitable for replacing the existing old means of electricity generation. Because, not only are they cheaper, but also economic and highly efficient. These turbines are gaining ground day by day and hopefully will be helpful in making us achieve the long sought-after goal of green and clean energy.

1. INTRODUCTION

Imagining a day without electricity in today's world is equivalent to a nightmare. Since its inception in early 19th century, Electricity's relevance has changed from a mere spark for illumination to a massive driving force behind gigantic tasks. Today, Electricity has become an inseparable part of every household. It has gained as much significance as that of food and water for people. From sowing to harvesting and cooking, everything has electricity embedded within it. It his helping reduce the labor involved while doing all sorts of tasks. Thus, it has helped create a strong, unbreakable bond with humans.

Present sources of Electricity Generation: Since the introduction of electricity, many diverse methods of producing electricity have evolved. Some of them are as follows:

Thermal Energy: Thermal Energy is the most conventional source of electric power. Thermal power plant is also referred as coal thermal power plant and steam turbine power plant.
A coal thermal power plant mainly consists of alternator runs with help of steam turbine. The steam is obtained from high pressure boilers. Generally in India, bituminous coal, brown coal and peat are used as fuel of boiler. The bituminous coal is used as boiler fuel has volatile matter from 8 to 33 % and ash content 5 to 16 %. To increase the thermal efficiency, the coal is used in the boiler in powder form.

Other Fossil Fuels: Other fossil fuels like diesel and natural gas are used for producing electricity. A fossil fuel power station is a power station which burns fossil fuel such as coal, natural gas, or petroleum to produce electricity.

Nuclear Energy: Nuclear Energy is the use of nuclear reactions which release nuclear energy to generate heat, which most frequently is then used in steam turbines to produce electricity in a nuclear power plant. The term includes nuclear fission, nuclear decay and nuclear fusion. Presently, the nuclear fission of elements in the actinide series of the periodic table produce the vast majority of nuclear energy in the direct service of humankind, with nuclear decay processes, primarily in the form of geothermal energy, and radioisotope thermoelectric generators, in niche uses making up the rest. Nuclear energy originates from the splitting of uranium atoms – a process called fission. This generates heat to produce steam, which is used by a turbine generator to generate electricity.

Hydro Energy: Hydro Energy is the energy of falling water or fast running water, which may be harnessed for useful purposes. Since ancient times, hydropower from many kinds of watermills has been used as a renewable energy source for irrigation and the operation of various mechanical devices, such as gristmills, sawmills, textile mills, trip hammers, dock cranes, domestic lifts, and ore mills. Electricity is generally produced through hydro energy by using the potential energy of water stored at a certain height above ground. This potential energy is used to rotate the turbines situated at the bottom and generate electricity.

Wave Energy: Wave Energy is generated due to winds, and is captured to do useful work – for example, electricity generation, water desalination, or the pumping of water (into reservoirs). Waves are generated by wind passing over the surface of the sea. As long as the waves propagate slower than the wind speed just above the waves, there is an energy transfer from the wind to the waves. Both air pressure differences between the upwind and the lee side of a wave crest, as well as friction on the water surface by the wind, making the water to go into the shear stress causes the growth of the waves. A machine able to exploit wave power is generally known as a wave energy converter (WEC).Wave power is distinct from the diurnal flux of tidal power and the steady gyre of ocean currents. Wave-power generation is not currently a widely employed commercial technology, although there have been attempts to use it since at least 1890.

Tidal Energy: Tidal energy is a form of hydropower that converts the energy obtained from tides into useful forms of power; mainly electricity Tidal power is taken from the Earth's oceanic tides. Tidal forces are periodic variations in gravitational attraction exerted by celestial bodies. These forces create corresponding motions or currents in the world's oceans.

Due to the strong attraction to the oceans, a bulge in the water level is created, causing a temporary increase in sea level. When the sea level is raised, water from the middle of the ocean is forced to move toward the shorelines, creating a tide. This occurrence takes place in an unfailing manner, due to the consistent pattern of the moon's orbit around the earth. The magnitude and character of this motion reflects the changing positions of the Moon and Sun relative to the Earth, the effects of Earth's rotation, and local geography of the sea floor and coastlines. Tidal power is the only technology that draws on energy inherent in the orbital characteristics of the Earth–Moon system, and to a lesser extent in the Earth–Sun system. Among sources of renewable energy, tidal power has traditionally suffered from relatively high cost and limited availability of sites with sufficiently high tidal ranges or flow velocities, thus constricting its total availability.

Ocean Energy: Ocean thermal energy conversion (OTEC) uses the temperature difference between cooler deep and warmer shallow or surface seawaters to run a heat engine and produce useful work, usually in the form of electricity. Systems may be either closed-cycle or open-cycle. Closed-cycle OTEC uses working fluids that are typically thought of as refrigerants such as ammonia or R-134a. These fluids have low boiling points, and are therefore suitable for powering the system's generator to generate electricity. The most commonly used heat cycle for OTEC to date is the Rankine cycle, using a low-pressure turbine.

Solar Energy: Solar energy is radiant light and heat from the Sun that is harnessed using a range of ever-evolving technologies such as solar heating, photovoltaics, solar thermal energy, solar architecture, molten salt power plants and artificial photosynthesis. It is an important source of renewable energy and its technologies are broadly characterized as either passive solar or active solar depending on how they capture and distribute solar energy or convert it into solar power. Active solar techniques include the use of photovoltaic systems, concentrated solar power and solar water heating to harness the energy. Passive solar techniques include orienting a building to the Sun, selecting materials with favorable thermal mass or light-dispersing properties, and designing spaces that naturally circulate air.

Wind Energy: Wind Energy is used to drive the wind turbines to mechanically power generators for electric power. Wind power, as an alternative to burning fossil fuels, is plentiful, renewable, widely distributed, clean, produces no greenhouse gas emissions during operation, consumes no water, and uses little land. The net effects on the environment are far less problematic than those of nonrenewable power sources.

Wind farms consist of many individual wind turbines which are connected to the electric power transmission network. Onshore wind is an inexpensive source of electric power, competitive with or in many places cheaper than coal or gas plants. Offshore wind is steadier and stronger than on land, and offshore farms have less visual impact, but construction and maintenance costs are considerably higher. Small onshore wind farms can feed some energy into the grid or provide electric power to isolated off-grid locations.

Wind power gives variable power which is very consistent from year to year but which has significant variation over shorter time scales. It is therefore used in conjunction with other electric power sources to give a reliable supply.

Fossil Fuel Power Plants:

Fossil fuel power plants produce environmental problems including land and water use, air emissions, thermal releases, climatic and visual impacts from cooling towers, solid waste disposal, ash disposal (for coal), and noise. Due to the need for large amounts of steam, plants can have a great effect on water use. For example, a typical 500 MW coal fired power plant uses 25 x 10^9 l/GW-year of water, which must be taken from a water source, and then cooled to return to the water source with as little environmental effect as possible. The biggest effect fossil fuel plants have overall is the emission of air pollutants, particularly SO_X, NO_X , CO, CO_2 , and hydrocarbons. Carbon monoxide, CO, carbon dioxide, CO_2, and the hydrocarbons are the "greenhouse gases," believed to be responsible for global warming. SO_X and NO_X produce acid when released into the atmosphere, leading to the production of acid rain. Table 2.6 list approximate amounts of airborne pollutants produced. Generally, air emissions are controlled by the use of scrubbers and precipitators located at the plant.

Plant Type	**CO**	**NO_X**	**SO_2**	**CO_2**
Coal	0.11	3.54	9.26	1090
Oil	0.19	2.02	5.08	781
Gas	0.20	2.32	0.004	490

Table 1.2: Power Plant Emissions (g/kWh)

Nuclear Power Plants: Nuclear power plants have one environmental issue no other form of electrical power plant does. An accident at a nuclear power plant may release large amounts of radioactive particles, possibly resulting in a direct loss of life, and rendering a large land area immediately around the plant unlivable. The largest regular environmental impact is the disposal of the high level nuclear waste contained in spent fuel rods, as this waste must be stored safely for thousands of years. There is no site in the United States currently accepting high level nuclear waste, so utilities are generally storing the waste in above ground casks at plant sites.

Hydro Energy: The use of hydropower to produce electricity can have both positive and negative effects on the environment. At some sites, a dam may help with flood control, flow regulation, or the reservoir may provide recreational opportunities. At other sites, the dam may have adverse effects on the hydrological cycle, water quality of the stream, stream ecology, fish migration, and cause the destruction of landscapes and ecosystems. Building new high-head dams require the displacement and compensation of populations. Low-head dams generally have a benign effect on the environment. Dam failures can lead to catastrophic floods.

1.5.1 Design Purpose

The purpose of this project is to design a portable and low cost power system that combines both wind electric and solar electric technologies. This hybrid system will be designed to deliver 15 watts of continuous power. The system is composed of a wind generator, a solar panel, a charge controller, a battery and an inverter. The solar panel and wind turbine work in tandem to charge a battery via a controller. After, an inverter will be used to convert DC power from the battery into AC power suitable for domestic use. The system will have a battery bank large enough to supply continuous electric load.

1.5.2 Project Objectives

The main objective of this project is to provide an alternative power solution for remote locations such as research areas and small villages. Also the system can be used as a temporary power solution for locations affected by natural disasters. In order to reach these objectives the product must be low cost and easy to manufacture.

1.5.3 Addressing Global Design

In order for this product to be a success amongst all types of users, there are many global design concepts which must be addressed and implemented. These types of design implementations are usually the ones that get the most overlooked, but we understand its importance and believe that it actually serves as the base of our project idea. The idea for this project came to mind when we realized the energy crisis which many developing nations around the globe are facing. In order for this product to improve the general well-being of these individuals, we believe it necessary and essential to incorporate the following key global design components

1.5.3.1 Design for manufacturability in different parts of the world

We understand that some materials and component sizes may not be readily available in some markets, and at times may take weeks or even months to source. In order to avoid these types of situations a design with easy to source components both locally and internationally will be developed.

The use of the aforementioned global design components is essential to having a successful product. For this reason, a great deal of time and effort has been put into their development.

CHAPTER-2

2.1 LITERARY REVIEW: For evaluating and designing the project, several resources' help has been taken. Precise information regarding various Solar and Wind phenomenon was procured from these resources. These sources provided immense help in understanding the total concept of Hybrid Power Generation and other topics closely related to it. The resources from which the knowledge for this project has been channeled are as follows:

Hybrid Power Generation System (*International Journal of Computer and Electrical Engineering, Vol.4, No.2, April 2012*): Combination of different but complementary energy generation systems based on renewable energies or mixed is known as hybrid system. In this paper a hybrid power system is designed with wind energy and hydro power source using PSCAD software. Here a simulation approach is adopted to observe the different characteristics of hybrid power system. From the study it is clear that this hybrid power system provides voltage stability and automatic load sharing capability.

Hybrid power systems are designed for the generation and use of electrical power. They are independent of a large, centralized electricity grid and incorporate more than one type of power source. They may range in size from relatively large island grids to individual household power supplies. In general a hybrid system might contain alternating current (AC) diesel generators, an AC distribution system, a DC distribution system, loads, renewable power sources, energy storage, power converters, rotary converters, coupled diesel system, dump loads, load management options or a supervisory control system.

A current and future state of art development of Hybrid Energy System using wind and PV-solar: A review (*Elsevier, Volume 13, Issue 8, October 2009*):

The wind and solar energy are omnipresent, freely available, and environmental friendly. The wind energy systems may not be technically viable at all sites because of low wind speeds and being more unpredictable than solar energy. The combined utilization of these renewable energy sources are therefore becoming increasingly attractive and are being widely used as alternative of oil-produced energy. Economic aspects of these renewable energy technologies are sufficiently promising to include them for rising power generation capability in developing countries.

A renewable hybrid energy system consists of two or more energy sources, a power conditioning equipment, a controller and an optional energy storage system. These hybrid energy systems are becoming popular in remote area power generation applications due to advancements in renewable energy technologies and substantial rise in prices of petroleum products. Research and development efforts in solar, wind, and other renewable energy technologies are required to continue for, improving their performance, establishing techniques for accurately predicting their output and reliably integrating them with other conventional generating sources. The aim of this paper is to review the current state of the design, operation and control requirement of the stand-alone PV solar–wind hybrid energy systems with conventional backup source i.e. diesel or grid. This Paper also highlights the future developments, which have the potential to increase the economic attractiveness of such systems and their acceptance by the user.

CHAPTER-3

3.1 HYBRID POWER GENERATION SYSTEM:

Combination of different but complementary energy generation systems based on renewable energies or mixed is known as hybrid system. Hybrid energy system is the combination of two energy sources for giving power to the load. In other word it can defined as "Energy system which is fabricated or designed to extract power by using two energy sources is called as the hybrid energy system." Hybrid energy system has good reliability, efficiency, less emission, and lower cost.

In this proposed system solar and wind power is used for generating power. Solar and wind has good advantages than other than any other non-conventional energy sources. Both the energy sources have greater availability in all areas. It needs lower cost. There is no need to find special location to install this s

3.1.1 Solar Energy: Solar energy is that energy which is gets by the radiation of the sun. Solar energy is present on the earth continuously and in abundant manner. Solar energy is freely available. It doesn't produce any gases that mean it is pollution free. It is affordable in cost. It has low maintenance cost. Only problem with solar system it cannot produce energy in bad weather condition. But it has greater efficiency than other energy sources. It only need initial investment. It has long life span and has lower emission.

Solar energy is a very fast-growing resource in today's world and is finding applications in several fields. But, its full scale use is yet to begin. It has the scope for powering industries and thus, reducing their complete dependence upon conventional fuels for basic needs.

3.1.2 Wind Energy: Wind energy is the energy which is extracted from wind. For extraction we use wind mill. Ii is renewable energy sources. The wind energy needs less cost for generation of electricity. Maintenance cost is also less for wind energy system. Wind energy is present almost 24 hours of the day. It has less emission. Initial cost is also less of the system. Generation of electricity from wind is depend upon the speed of wind flowing. The major disadvantages of using independent renewable energy resources are that unavailability of power for all time. For overcoming this we use solar and wind energy together. So that any one source of power fails other will take care of the generation. In this proposed system we can use both sources combine. Another way is that we can use any one source and keep another source as a stand by unit. This will leads to continuity of generation. This will make system reliable. The main disadvantages of this system are that it needs high initial cost. Except that it is reliable, it has less emission. Maintenance cost is less. Life span of this system is more. Efficiency is more.

CHAPTER-4

4.1 Prevalence of Solar Power in India:

4.1.1 Current Status: Solar power in India is a fast-growing phenomenon. As of 6 April 2017, the country's solar grid had a cumulative capacity of 12.28 gig watts (GW) compared to 6.76 GW at the end of March 2016. In January 2015, the India expanded its solar plans, targeting US$100 billion of investment and 100 GW of solar capacity, including 40 GW from rooftop solar, by 2022. India's initiative of 100 GW of solar energy by 2022 is an ambitious target given the world's installed solar power capacity in 2014 was 181 GW.

India quadrupled its solar power generation capacity from 2,650 MW on 26 May 2014 to 12,288.83 MW on 10 March 2017. The country added 3.01 GW of solar power capacity in 2015-2016, and 5.525 GW in 2016-2017, the highest of any year. In addition to the large-scale grid connected solar PV initiative, India is continuing to develop the use of off-grid solar power for localized energy needs.

India has a poor electrification rate in rural areas. In 2015, only 55% of all rural households had access to electricity, and 85% of rural households depended on solid fuel for cooking. Solar products have increasingly helped to meet rural needs, and by the end of 2015, a cumulative total of just fewer than 1 million solar lanterns had been sold in the country, reducing the need for expensive kerosene. During 2015 alone, 118,700 solar home lighting systems were installed, and 46,655 solar street lighting installations were provided under a national program. The same year saw just over 1.4 million solar cookers distributed or sold in India.

India is one of the countries with the higher solar electricity production per watt installed, with an insolation of 1700 to 1900 kilowatt hours per kilowatt peak (kWh/KWp). On 16 May 2011, India's first solar power project under clean development mechanism is in is in Sivagangai Village, Tamil Nadu. India saw a sudden rise in use of solar electricity in 2010, when 25.1 MW was added to the grid, and the trend accelerated when 468.3 MW was added in 2011. Recent growth has been over 3,000 MW per year and is set to increase yet further.

With about 300 clear, sunny days in a year, the theoretically calculated solar energy incidence on India's land area is about 5000 trillion kilowatt-hours (kWh) per year (or 5 EWh/yr). The solar energy available in a year exceeds the possible energy output of all fossil fuel energy reserves in India. The daily average solar power plant generation capacity over India is 0.20 kWh per m^2 of used land area, which is equivalent to about 1400–1800 peak (rated) capacity operating hours in a year with the available commercially-proven technologies.

So, by the given facts above, it can be seen that solar power generation is gaining ground gradually in India. But, much more work needs to be done in order to produce a substantial amount of electricity throughout the country through solar power.

4.2 Solar Power Generation Techniques:

Generation of electricity using solar energy can be done in several ways. There are many methods through which Solar Energy can be easily converted into desired type of electricity with respect to voltage and current. Some of the methods are:

4.2.1 Power Generation through Photovoltaic Cells:

Photovoltaic cells produce electricity directly from sunlight. Photovoltaic cells are also called PV cells or solar cells. A typical photovoltaic system employs solar panels, each comprising a number of solar cells, which generate electrical power. PV installations may be ground-mounted, rooftop mounted or wall mounted. The mount may be fixed, or use a solar tracker to follow the sun across the sky.

Fig 4.2: Solar Photovoltaic Cell

Many PV cells are used in remote locations not connected to the electric grid. Photovoltaic cells comprise the main component in solar panels and are also used to power watches, calculators, solar lights, and lighted road signs. When sunlight strikes a solar cell, electrons are knocked loose. They move toward the treated front surface. An electron imbalance is created between the front and the back. When a connector, like a wire, joins the two surfaces a current of electricity occurs between the negative and positive sides.

Photovoltaic cells, like batteries, generate direct current (DC), which is generally used for small loads (electronic equipment). When DC from photovoltaic cells is used for commercial applications or sold to electric utilities using the electric grid, it must be converted to alternating current (AC) using grid inverters, solid-state devices that convert DC power to AC.

Solar PV has specific advantages as an energy source as its operation generates no pollution and no greenhouse gas emissions once installed, it shows simple scalability in respect of power needs and silicon has large availability in the Earth's crust.

4.2.2 Power Generation through Solar Thermal Collectors:

A solar thermal collector collects heat by absorbing sunlight. A collector is a device for capturing solar radiation. Solar radiation is energy in the form of electromagnetic radiation from the infrared (long) to the ultraviolet (short) wavelengths. The quantity of solar energy striking the Earth's surface (solar constant) averages about 1,000 watts per square meter under clear skies, depending upon weather conditions, location and orientation.

Fig 4.3: Solar Collector Plate

The term "solar collector" commonly refers to solar hot water panels, but may refer to installations such as solar parabolic troughs and solar towers; or basic installations such as solar air heaters. Concentrated solar power plants usually use the more complex collectors to generate electricity by heating a fluid to drive a turbine connected to an electrical generator. Simple collectors are typically used in residential and commercial buildings for space heating. The first solar thermal collector designed for building roofs was patented by William H. Goettl and called the "Solar heat collector and radiator for building roof".

Solar collectors are either non-concentrating or concentrating. In the non-concentrating type, the collector area (the area that intercepts the solar radiation) is the same as the absorber area (the area absorbing the radiation). In these types the whole solar panel absorbs light. Concentrating collectors have a bigger interceptor than absorber. Flat-plate and evacuated-tube solar collectors are used to collect heat for space heating, domestic hot water or cooling with an absorption chiller.

4.2.3 Power Generation through Solar Concentrators:

Concentrated solar power systems, also called concentrating solar power, concentrated solar thermal, and CSP systems generate solar power by using mirrors or lenses to concentrate a large area of sunlight, or solar thermal energy, onto a small area. Electricity is generated when the concentrated light is converted to heat, which drives a heat engine (usually a steam turbine) connected to an electrical power generator or powers a thermo chemical reaction) Heat storage in molten salts allows some solar thermal plants to continue to generate after sunset and adds value to such systems when compared to photovoltaic panels.

Fig 4.4: Solar Concentrator

CSP is used to produce electricity, called solar thermoelectricity, usually generated through steam.

Concentrated-solar technology systems use mirrors or lenses with tracking systems to focus a large area of sunlight onto a small area. The concentrated light is then used as heat or as a heat source for a conventional power plant (solar thermoelectricity). The solar concentrators used in CSP systems can often also be used to provide industrial process heating or cooling, such as in conditioning. Concentrating technologies exist in five common forms, namely parabolic trough, enclosed trough, dish Stirlings, concentrating linear Fresnel reflector, and solar power tower. Although simple, these solar concentrators are quite far from the theoretical maximum concentration. For example, the parabolic-trough concentration gives about ⅓ of the theoretical maximum for the design acceptance angle, that is, for the same overall tolerances for the system. Approaching the theoretical maximum may be achieved by using more elaborate concentrators based on non-imaging optics.

Different types of concentrators produce different peak temperatures and correspondingly varying thermodynamic efficiencies, due to differences in the way that they track the sun and focus light. New innovations in CSP technology are leading systems to become more and more cost-effective.

4.2.4 Power Conservation through Passive Solar Building Design:

In passive solar building design, windows, walls, and floors are made to collect, store, and distribute solar energy in the form of heat in the winter and reject solar heat in the summer. Though it does not involve production of electricity, it helps in conserving energy and reducing costs to a large scale. This is called passive solar design because, unlike active solar heating systems, it does not involve the use of mechanical and electrical devices.

4.3 Solar Power Generation Unit in Hybrid Power System:

The Solar component of Hybrid power generation system comprises of two basic components: The Solar Panel and Solar Tracking system. Both these parts are connected to the control unit which constantly monitors and sends commands to control the functioning of both of them. In this type of combination, the Solar Panel is not the lone source for electricity production. Even the Solar Tracking system is capable of producing electricity. So, we have two sources side-by-side to produce electricity – which means less effort and more electricity.

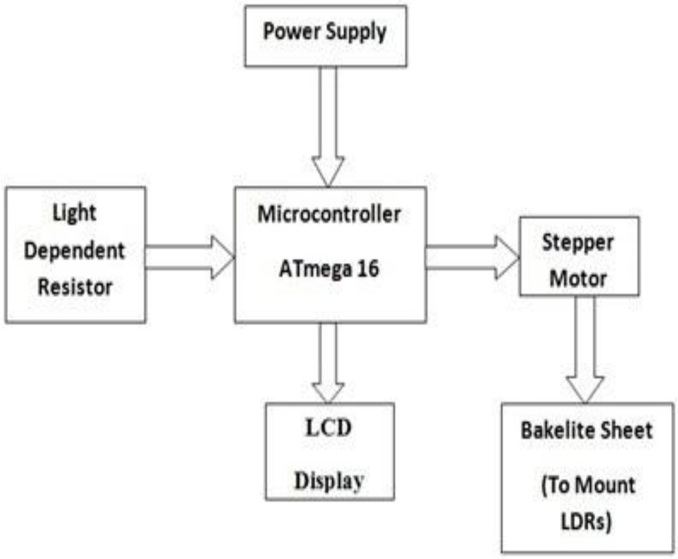


Fig 3.5: Block Diagram of Solar Tracking System

4.3.1 Solar panel:

Solar panel refers to a panel designed to absorb the sun's rays as a source of energy for generating electricity or heating.

A photovoltaic (PV) module is a packaged, connect assembly of typically 6×10 photovoltaic solar cells. Photovoltaic modules constitute the photovoltaic array of a photovoltaic system that generates and supplies solar 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 365 watts. 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 a few commercially available solar modules that exceed 22% efficiency and reportedly also exceeding 24%. A single solar module can produce only a limited amount of power; most installations contain multiple modules.

Fig 3.6: Solar Plate

Photovoltaic modules use light energy (photons) from the Sun to generate electricity through the photovoltaic effect. The majority of modules use wafer-based crystalline silicon cells or thin-film cells. The cells must be connected electrically in series, one to another Operating silently and without any moving parts or environmental emissions, PV systems have developed from being niche market applications into a mature technology used for mainstream electricity generation. A rooftop system recoups the invested energy for its manufacturing and installation within 0.7 to 2 years and produces about 95 percent of net clean renewable energy over a 30-year service lifetime.

4.3.2 Description of Solar Tracking System:

One of the most promising renewable energy sources characterized by a huge potential of conversion into electrical power is the solar energy. The conversion of solar radiation into electrical energy by Photo-Voltaic (PV) effect is a very promising technology, being clean, silent and reliable, with very small maintenance costs and small ecological impact. The interest in the Photo Voltaic conversion systems is visibly reflected by the exponential increase of sales in this market segment with a strong growth projection for the next decades. According to recent market research reports carried out by European Photovoltaic Industry Association (EPIA), the total installed power of PV conversion equipment increased from about 1 GW in 2001up to nearly 23 GW in 2009.

Principle:

The continuous modification of the sun-earth relative position determines a continuously changing of incident radiation on a fixed PV panel. The point of maximum received energy is reached when the direction of solar radiation is perpendicular on the panel surface. Thus an increase of the output energy of a given PV panel can be obtained by mounting the panel on a solar tracking device that follows the sun trajectory. Unlike the classical fixed PV panels, the mobile ones driven by solar trackers are kept under optimum insolation for all positions of the Sun, boosting thus the PV conversion efficiency of the system. The output energy of PV panels equipped with solar trackers may increase with tens of percents, especially during the summer when the energy harnessed from the sun is more important. Photo-Voltaic or PV cells, known commonly as solar cells, convert the energy from sunlight into DC electricity. PVs offer added advantages over other renewable energy sources in that they give off no noise and require practically no maintenance. A tracking system must be able to follow the sun with a certain degree of accuracy, return the collector to its original position at the end of the day and also track during periods of cloud over.

The major components of this system are as follows.

Light dependent resistor
Micro-controller
Output mechanical transducer (stepper motor)

Background

A Solar Tracker is a device onto which solar panels are fitted which tracks the motion of the sun across the sky ensuring that the maximum amount of sunlight strikes the panels throughout the day. The Solar Tracker will attempt to navigate to the best angle of exposure of light from the sun. This report aims to let the reader understand the project work which I have done. Basically the Solar Tracker is divided into two main categories, hardware and software. It is further subdivided into six main functionalities: Method of Tracker Mount, Drives, Sensors, RTC, Motors, and Power Supply of the Solar Tracker is also explained and explored. The reader would then be brief with some analysis and perceptions of the information.

Need for using Solar Tracking System:

By using solar arrays, a series of solar cells electrically connected, a DC voltage is generated which can be physically used on a load. Solar arrays or panels are being used increasingly as efficiencies reach higher levels, and are especially popular in remote areas where placement of electricity lines is not economically viable. This alternative power source is continuously achieving greater popularity especially since the realisation of fossil fuels shortcomings. Renewable energy in the form of electricity has been in use to some degree as long as 75 or 100 years ago.

Sources such as Solar, Wind, Hydro and Geothermal have all been utilised with varying levels of success. The most widely used are hydro and wind power, with solar power being moderately used worldwide. This can be attributed to the relatively high cost of solar cells and their low conversion efficiency. Solar power is being heavily researched, and solar energy costs have now reached within a few cents per kW/h of other forms of electricity generation, and will drop further with new technologies such as titanium oxide cells. With a peak laboratory efficiency of 32% and average efficiency of 15-20%, it is necessary to recover as much energy as possible from a solar power system. This includes reducing inverter losses, storage losses, and light gathering losses. Light gathering is dependent on the angle of incidence of the light source providing power (i.e. the sun) to the solar cell's surface, and the closer to perpendicular, the greater the power. If a flat solar panel is mounted on level ground, it is obvious that over the course of the day the sunlight will have an angle of incidence close to 90° in the morning and the evening. At such an angle, the light gathering ability of the cell is essentially zero, resulting in no output. As the day progresses to midday, the angle of incidence approaches 0°, causing a steady increase in power until at the point where the light incident on the panel is completely perpendicular, and maximum power is achieved. As the day continues toward dusk, the reverse happens, and the increasing angle causes the power to decrease again toward minimum again.

4.3.3 Solar Tracker: Solar Tracker is basically a device onto which solar panels are fitted which tracks the motion of the sun across the sky ensuring that the maximum amount of sunlight strikes the panels throughout the day. After finding the sunlight, the tracker will try to navigate through the path ensuring the best sunlight is detected. The design of the Solar Tracker requires many components. The design and construction of it could be divided into six main parts that would need to work together harmoniously to achieve a smooth run for the Solar Tracker, each with their main function. They are:

1. Methods of Tracker Mount
2. Methods of Drives
3. Sensor and Sensor Controller
4. Motor and Motor Controller

1. Methods of Tracker Mount

a. **Single axis solar trackers :** Single axis solar trackers can either have a horizontal or a vertical axle. The horizontal type is used in tropical regions where the sun gets very high at noon, but the days are short. The vertical type is used in high latitudes where the sun does not get very high, but summer days can be very long. The single axis tracking system is the simplest solution and the most common one used.
b. **Double axis solar trackers:** Double axis solar trackers have both a horizontal and a vertical axle and so can track the Sun's apparent motion exactly anywhere in the World. This type of system is used to control astronomical telescopes, and so there is plenty of software available to automatically predict and track the motion of the sun across the sky. By tracking the sun, the efficiency of the solar panels can be increased by 30-40%.The dual axis tracking system is also used for concentrating a solar reflector toward the concentrator on heliostat systems.

2. Methods of Drive

a. Active Trackers

Active Trackers use motors and gear trains to direct the tracker as commanded by a controller responding to the solar direction. Light-sensing trackers typically have two photo sensors, such as photodiodes, configured differentially so that they output a null when receiving the same light flux. Mechanically, they should be unidirectional and are aimed 90 degrees apart. This will cause the steepest part of their cosine transfer functions to balance at the steepest part, which translates into maximum sensitivity.

b. Passive Trackers

Passive Trackers use a low boiling point compressed gas fluid that is driven to one side or the other by solar heat creating gas pressure to cause the tracker to move in response to an imbalance.

3. Sensors

A sensor is a device that measures a physical quantity and converts it into a signal which can be read by an observer or by an instrument.

4. DC Motor:

A **DC motor** is any of a class of rotary electrical machines that converts direct current electrical power into mechanical power. The most common types rely on the forces produced by magnetic fields. Nearly all types of DC motors have some internal mechanism, either electromechanical or electronic; to periodically change the direction of current flow in part of the motor.

DC motors were the first type widely used, since they could be powered from existing direct-current lighting power distribution systems. A DC motor's speed can be controlled over a wide range, using either a variable supply voltage or by changing the strength of current in its field windings. Small DC motors are used in tools, toys, and appliances. The universal motor can operate on direct current but is a lightweight motor used for portable power tools and appliances. Larger DC motors are used in propulsion of electric vehicles, elevator and hoists, or in drives for steel rolling mills. The advent of power electronics has made replacement of DC motors with AC motors possible in many applications.

A coil of wire with a current running through it generates an electromagnetic field aligned with the center of the coil. The direction and magnitude of the magnetic field produced by the coil can be changed with the direction and magnitude of the current flowing through it.

A simple DC motor has a stationary set of magnets in the stator and an armature with one or more windings of insulated wire wrapped around a soft iron core that concentrates the magnetic field. The windings usually have multiple turns around the core, and in large motors there can be several parallel current paths. The ends of the wire winding are connected to a commutator. The commutator allows each armature coil to be energized in turn and connects the rotating coils with the external power supply through brushes. (Brushless DC motors have electronics that switch the DC current to each coil on and off and have no brushes.) The total amount of current sent to the coil, the coil's size and what it's wrapped around dictate the strength of the electromagnetic field created.

The sequence of turning a particular coil on or off dictates what direction the effective electromagnetic fields are pointed. By turning on and off coils in sequence a rotating magnetic field can be created. These rotating magnetic fields interact with the magnetic fields of the magnets (permanent or electromagnets) in the stationary part of the motor (stator) to create a force on the armature which causes it to rotate. In some DC motor designs the stator fields use electromagnets to create their magnetic fields which allow greater control over the motor. At high power levels, DC motors are almost always cooled using forced air.

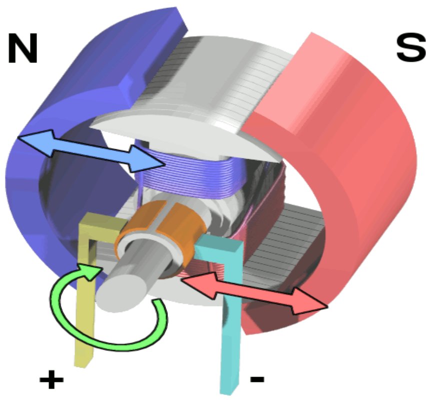


Fig 4.9: DC Motor

DC motors can operate directly from rechargeable batteries, providing the motive power for the first electric vehicles and today's hybrid cars and electric cars as well as driving a host of cordless tools. Today DC motors are still found in applications as small as toys and disk drives, or in large sizes to operate steel rolling mills and paper machines. Large DC motors with separately excited fields were generally used with winder drives for mine hoists, for high torque as well as smooth speed control using thyristor drives. These are now replaced with large AC motors with variable frequency drives.

If external power is applied to a DC motor it acts as a DC generator, a dynamo. This feature is used to slow down and recharge batteries on hybrid car and electric cars or to return electricity back to the electric grid used on a street car or electric powered train line when they slow down. This process is called regenerative braking on hybrid and electric cars. In diesel electric locomotives they also use their DC motors as generators to slow down but dissipate the energy in resistor stacks. Newer designs are adding large battery packs to recapture some of this energy.

Working:

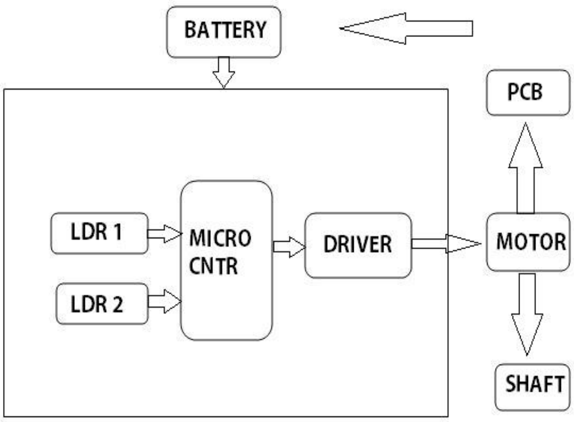


Fig 4.10: Solar Tracking System

When the sensors track the direction of the sun and the angle, they send back the signals to the control unit. The control unit then issues a command to run the DC motor in order to align the solar panel such that it receives maximum sunshine again. The movement of DC motor during alignment results in generation of electricity due to the movement of its shaft.

4.4 Solar Panel Energy Calculations:

Capacity of Unit: 10 W/h Volts: 12V Period for which Solar Panel is exposed to Sun in Summer
(Ts): 9 hrs Period for which Solar Panel is exposed to Sun in Winter
(Tw): 7hrs Total Power per Day(Ps): 90W /day
If Losses are included,
(The rated power of Solar Panel* the no. of hrs of Sunshine* Dust, Weak Radiation * Efficiency of Charge

Controller)
Power (Ps)= 10*9*0.90*0.85= 64.8Watts/Day)

The power generated by the solar unit (including losses) lies within the range of the power that has been obtained in the calculations. Power generated is different for each and every hour. It basically depends upon the time of the day and the solar irradiance at that particular time. By ascertaining the magnitude of power generated with the help of calculations, efforts can be made in order to improve the power generation ability of the solar panel unit.

4.5 Solar Tracking Unit Calculations:

DC Motor Capacity: 0.002 HP Volts (V_{st}): 5V Speed (N_{st}): 10 RPM

Multimeter Readings:

Current (I_{st}) = 0.2Amp/hrs Power (P_{st}) =V_{st}*I_{st} =5 V* 0.2 Amps

Power Generated (P_{st}) =1W

This is the power that is generated during the tracking process. The rotation of DC Motor contributes to EMF which eventually leads to current flow.

CHAPTER-5

5.1 Wind Power:

Wind Energy, like solar is a free energy resource. But is much intermittent than solar. Wind speeds may vary within minutes and affect the power generation and in cases of high speeds- may result in overloading of generator.

Energy from the wind can be tapped using turbines. Setting up of these turbines needs little research before being established. Be it a small wind turbine on a house, a commercial wind farm or any offshore installation, all of them, at first, need the Wind Resource to be determined in the area of proposed site. The Wind Resource data is an estimation of average and peak wind speeds at a location based on various meteorological. The next step is to determine access to the transmission lines or nearest control centre where the power generated from the turbines can be conditioned, refined, stored or transmitted. It is also necessary to survey the impact of putting up wind turbines on the community and wildlife in the locality. If sufficient wind resources are found, the developer will secure land leases from property owners, obtain the necessary permits and financing; purchase and install wind turbines. The completed facility is often sold to an independent operator called an independent power producer (IPP) who generates electricity to sell to the local utility, although some utilities own and operate wind farms directly.

5.1.1 Prevalence of Wind Power in India:

Wind power generation capacity in India has significantly increased in the last few years and as of 31 January 2017 the installed capacity of wind power was 28,871.59 MW, mainly spread across the South, West and North regions. By year end 2015 India had the fourth largest installed wind power capacity in the world. The development of wind power in India began in 1986 with the first wind farms being set up in coastal areas of Maharashtra, Gujarat and Tamil Nadu with 55 kW Vestas wind turbines. These demonstration projects were supported by the Ministry of New and Renewable Energy (MNRE).

East and North east regions have no grid connected wind power plant. No offshore wind farm utilizing traditional fixed-bottom wind turbine technologies in shallow sea areas or floating wind turbine technologies in deep sea areas are under implementation. However, an Offshore Wind Policy was announced in 2015 and presently weather stations and LIDARs are being set up by NIWE at some locations.

The potential for Wind Energy in India is far from exhausted. It is estimated that with the current level of technology, the 'on-shore' potential for utilization of wind energy for electricity generation is of the order of 65,000 MW. India also is blessed with 7517km of coastline and its territorial waters extend up to 12 nautical miles into the sea. The unexploited resource availability has the potential to sustain the growth of wind energy sector in India in the years to come. Potential areas can be identified on Indian map using Wind Power Density map. C-WET, one of pioneering Wind Research organization in the country is leading in all such resource studies and has launched its Wind Resource map.

Electricity losses in India during transmission and distribution have been extremely high over the years and this reached a worst proportion of about 24.7% during 2010-11. India is in a pressing need to tide over a peak power shortfall of 13% by reducing losses due to theft. Theft of electricity, common in most parts of urban India, amounts to 1.5% of India's GDP. Due to shortage of electricity, power cuts are common throughout India and this has adversely affected the country's economic growth. Hence a cheaper, non-polluting and environment friendly solution to power rural India is needed.

5.2 Wind Power Generation:

Wind Power is harnessed and converted into electricity with the help of wind turbines. A wind turbine is a device that converts the wind's kinetic energy into electrical power.

Wind turbines are manufactured in a wide range of vertical and horizontal axis types. The smallest turbines are used for applications such as battery charging for auxiliary power for boats or caravans or to power traffic warning signs. Slightly larger turbines can be used for making contributions to a domestic power supply while selling unused power back to the utility supplier via the electrical grid. Arrays of large turbines, known as wind farms, are becoming an increasingly important source of intermittent renewable energy and are used by many countries as part of a strategy to reduce their reliance on fossil fuels.

5.3 Types of Wind Turbines:

Wind turbines can rotate about either a horizontal or a vertical axis. Horizontal Wind Turbines are both older and more common. They can also include blades (transparent or not) or be bladeless. Vertical designs produce less power and are less common but are highly efficient and more eco-friendly when compared to Horizontal Wind turbines.

5.3.1 Horizontal Axis Wind Turbines:

Horizontal-axis wind turbines (HAWT) have the main rotor shaft and electrical generator at the top of a tower, and must be pointed into the wind. Small turbines are pointed by a simple wind vane, while large turbines generally use a wind sensor coupled with a servo motor. Most have a gearbox, which turns the slow rotation of the blades into a quicker rotation that is more suitable to drive an electrical generator.

Fig 5.2: Horizontal Axis Wind Turbine

5.3.2 Vertical Axis Wind Turbines:

Vertical-axis wind turbines (VAWTs) are a type of wind turbine where the main rotor shaft is set transverse to the wind (but not necessarily vertically) while the main components are located at the base of the turbine. This arrangement allows the generator and gearbox to be located close to the ground, facilitating service and repair. VAWTs do not need to be pointed into the wind, which removes the need for wind-sensing and orientation mechanisms. A VAWT tipped sideways, with the axis perpendicular to the wind streamlines, functions similarly. A more general term that includes this option is "transverse axis wind turbine" or "cross-flow wind turbine. Drag-type VAWTs such as the Savonius rotor typically operate at lower tipspeed ratios than lift-based VAWTs such as Darrieus rotors and cycloturbines. Vertical turbines spin on the vertical axis and come in various shapes sizes and colors. It's movement is similar to a coin spinning on the edge. The main difference between the VAWT and HAWT is the position of blades.

Vertical Axis Wind Turbines are designed to be economical and practical, as well as quiet and efficient. They are great for use in residential areas whereas the HAWT is best for use at a business location. There are two different styles of vertical wind turbines out there. One is

Fig 4.3: Vertical Axis Wind Turbine

Types of Vertical Axis Wind Turbines:

They are basically of two types:

1) Darrieus Wind Turbine:

Darrieus Wind Turbine is commonly known as an "Eggbeater" turbine. It was invented by Georges Darrieus in 1931. A Darrieus is a high speed, low torque machine suitable for generating alternating current (AC) electricity. Darrieus generally require manual push therefore some external power source to start turning as the starting torque is very low. Darrieus has two vertically oriented blades revolving around a vertical shaft.

These eggbeater shaped turbines are great at efficiency, however, they are not as reliable.In order to use the Darrieus wind turbine you must have an outside source of power in order to start them.

2) Savonius Wind Turbine:

A Savonius vertical-axis wind turbine is a slow rotating, high torque machine with two or more scoops and is used in high-reliability low-efficiency power turbines. Most wind turbines use lift generated by airfoil-shaped blades to drive a rotor, the Savonius uses drag and therefore cannot rotate faster than the approaching wind speed.

The Savonius wind turbine is the most popular of the two types. As a drag type of turbine, these units are less efficient. This unit is larger than the Darrieus model. Savonius vertical axis wind turbine needs to be manually started. The slow speed of Savonius increases cost and produces less efficiency.

5.4 Wind Power Generation System:

The wind generation unit consists of Vertical axis wind turbine, Having Aluminum blades across its set up. These Aluminum blades absorb Kinetic Energy & Potential energy of the wind and start to rotate. These rotations act as an input for the DC Generator (5v). The shaft in the DC Generator rotates along with the blades. This movement around the armature induces emf that contributes to Electricity. This setup constitutes the wind power generation unit of the Hybrid Power System. It runs on wind energy and generates electricity due to rotation of blades. The more the wind, the more is the generation of electricity.

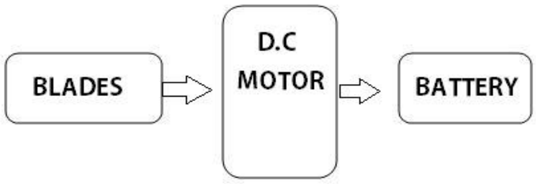


Fig 5.4: Block Diagram of Wind Power Generation System

Aluminum blades were cut from Al alloy sheets, and bended to shapes with regards to the calculations. They were attached to plywood plates using L bits, Nuts & Bolts.5 blades were attached after designing in the CAD software (Solidworks). Rubber padding was used to couple the blade moment with the DC generator. Magnets are used to constrain the motion and to avoid run out.

5.5 Design of Vertical Axis Wind Turbine Blades:

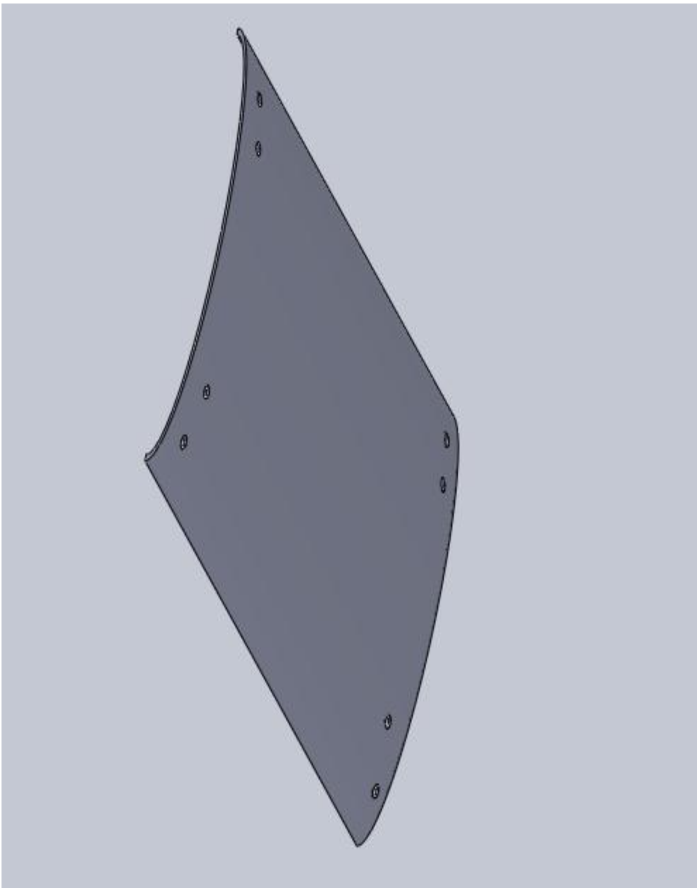


Fig 5.5

5.5.1 Design of L-Clamps:

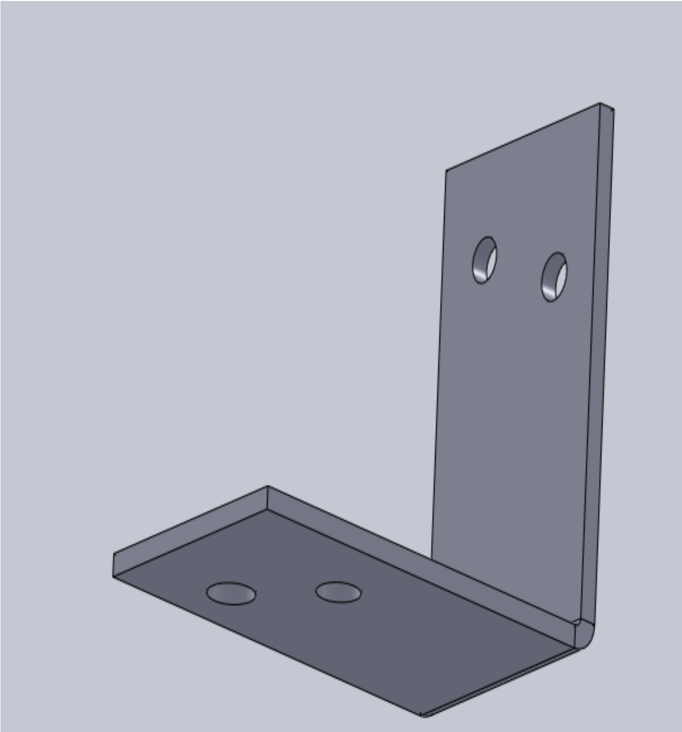


Fig 5.6

5.6 Analysis of VAWT Blade using ANSYS:

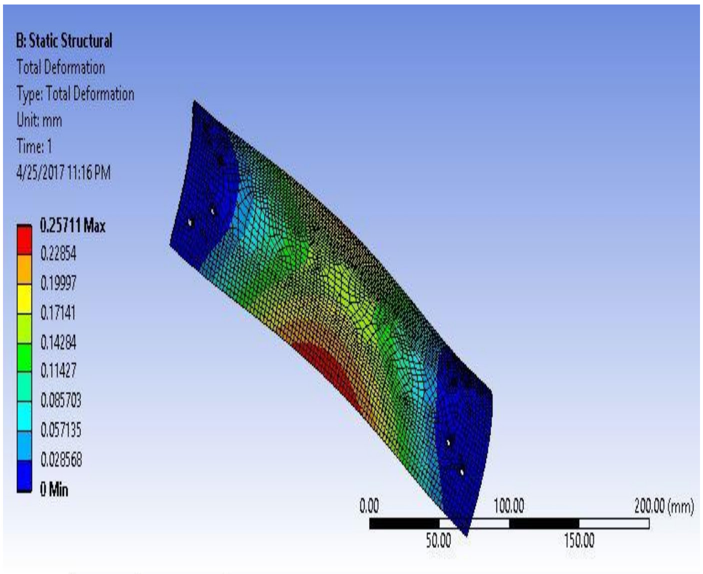


Fig 5.7

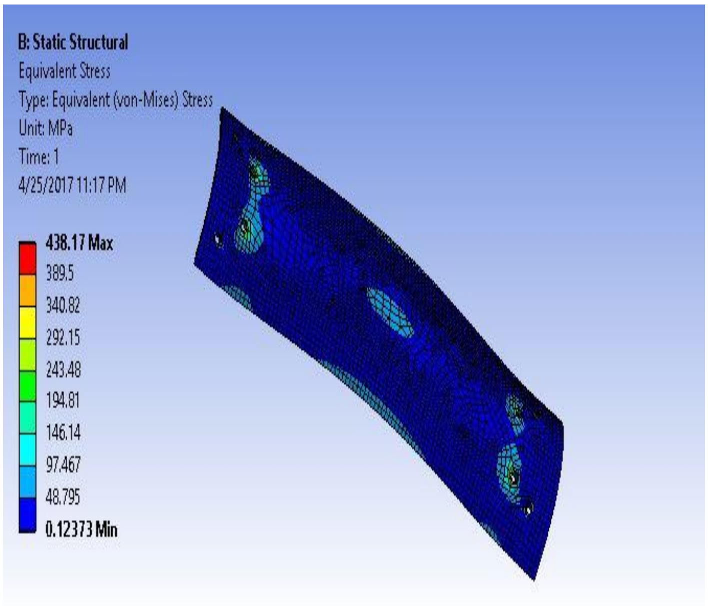


Fig 5.8

5.7 Wind Power Generation Unit Calculations:

Kinetic Energy of Wind:

$P=1/2*\rho*A*V^3$
(P=Power, ρ=density, A= swift area, V= velocity of wind)
$p = 1/2 * 1.125 *0.04575 * 5^3 = 3.21 \text{ kg m}^2 /s^3$

Multimeter Reading:

I = 0.2 amps/min
Power (P) = V*I =12*0.2
Power (P) =2.4 W/min (if Wind Flow is continuous and V =5 m/s)

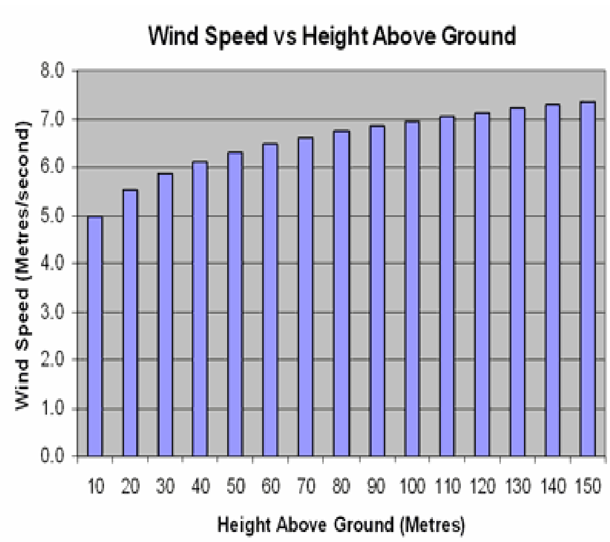


Fig 5.9: Variation of Wind with Altitudes

The above bar graph shows the variation of wind speeds along with changing altitudes. As is specified from the bar-chart, as the altitude increases, the wind gradually increases to a higher value. From this it could be understood that higher the altitude, higher is the wind power. So, it is clear that turbines installed at higher altitudes are capable of generating more power when compared to those situated at lower altitudes.

CHAPTER-6

6.1 HYBRID POWER GENERATION SYSTEM:

Hybrid models have been an effective means of producing generating electricity throughout the world. Lots of research work has been done and continuing the accommodate new advances in this system. This paper reports the probabilistic performance assessment of a wind, Solar Photo Voltaic (SPV) Hybrid Energy System. In addition to this solar/wind system with backup storage batteries were designed, integrated and optimized to predict the behavior of generating system. This paper proposes a hybrid energy system combining solar photovoltaic and wind turbine as a small scale alternative source of electrical energy where conventional generation is not practical.

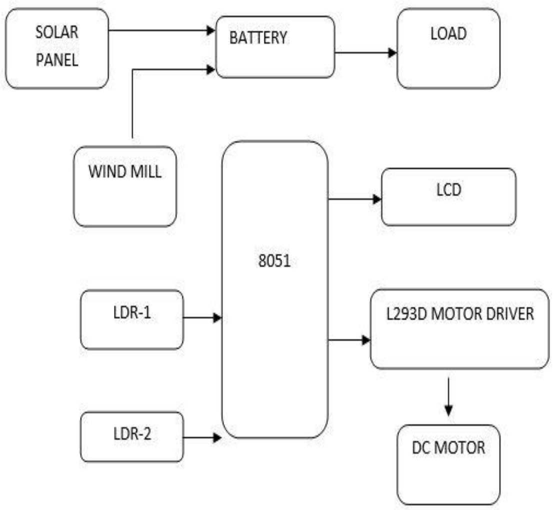


Fig 6.1: Combined Hybrid Generation System

6.2 Combined Sequence of Operations:

The LDR first detects the sunlight. The Resistor then identifies the direction of sunlight and sends back the signal to the Tracking Control Unit (T.C.U). The IC in the T.C.U receives this signal and processes this input. It uses a C-Program in order to process this signal. This signal is then transferred to the driving unit. This unit then processes this signal in order to form a command. This command is called as the driving command.

This driving command generated by the driving IC is transferred to the DC motor. The DC motor, acting upon this command, rotates accordingly to align the solar panel attached to it. Due to the rotation of DC Motor, the solar panel moves until it again reaches the maximum irradiation position.

The solar panel is now set and the current generated due to the rotation of the shaft of DC motor is transmitted and stored in the battery.

6.3 LOAD CIRCUIT:

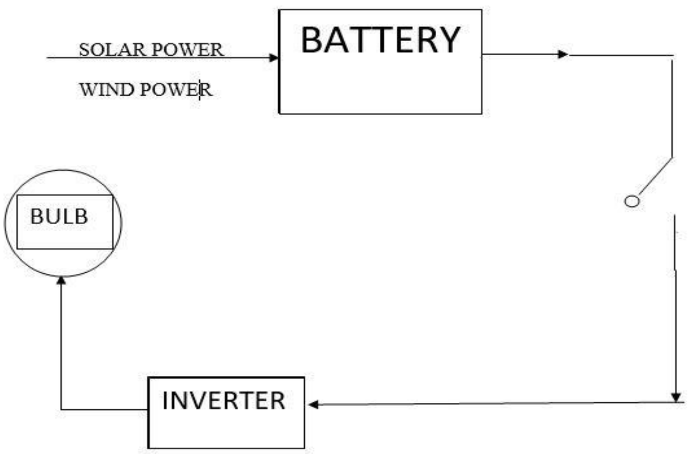


Fig 6.2

The combination of solar power and wind power coming from the Solar Panels & VAWT are stored in the 12V Battery. A switch is used to regulate the power supply between the battery and the inverter. A **power inverter**, or **inverter**, is an electronic device or circuitry that changes direct current (DC) to alternating current (AC).

The inverter consists of MOSFET & Step up transformer to increase the voltage of the incoming charge so as to light a 15W bulb. When the switch is ON, the circuit is closed and current passes to the bulb lighting it. In this way, the bulb is lighted up. Its approximate glowing time depends upon the amount of sunlight incident upon the setup i.e. irradiance and the type of wind flow. For more irradiance and wind flow, we get more illumination time for the bulb. Availability of higher capacity batteries also could help increase the illumination time due to increased storage of power within those batteries.

CHAPTER – 7

7.1 METHODOLOGY:

The methodology adopted for testing the Hybrid System has been divided into two segments:

7.1.1 Working Analysis for Solar Unit:

For assessing the ability to generate solar power, the solar unit is placed under sun throughout the day. It is initiated under nil battery condition. For the first hour (i.e., from 10 am-11am), it accepts solar energy and generated power. This power is simultaneously stored in the battery. The solar power generated during this hour is noted down. In the next hour (i.e. from 11am-12pm), the battery is completely drained such that the charge becomes nil again. This is done so as to separately determine power generated in each respective hour. The time for complete battery discharge is approximately 50 minutes. In the next hour (12pm – 1pm), the solar panel is again made to accept energy and generate power. This power is stored in the battery. The power generated for this hour is noted down. The same method of alternately charging and discharging battery and noting down the power generated whilst charging for each respective hour is followed. The results are plotted in the form of a bar graph (shown in fig 6.2).

This testing method is considered quite effective as it helps to assess the power generation for every hour with a good amount of accuracy. Draining out of battery increases the level of accuracy in the assessment of power generation.

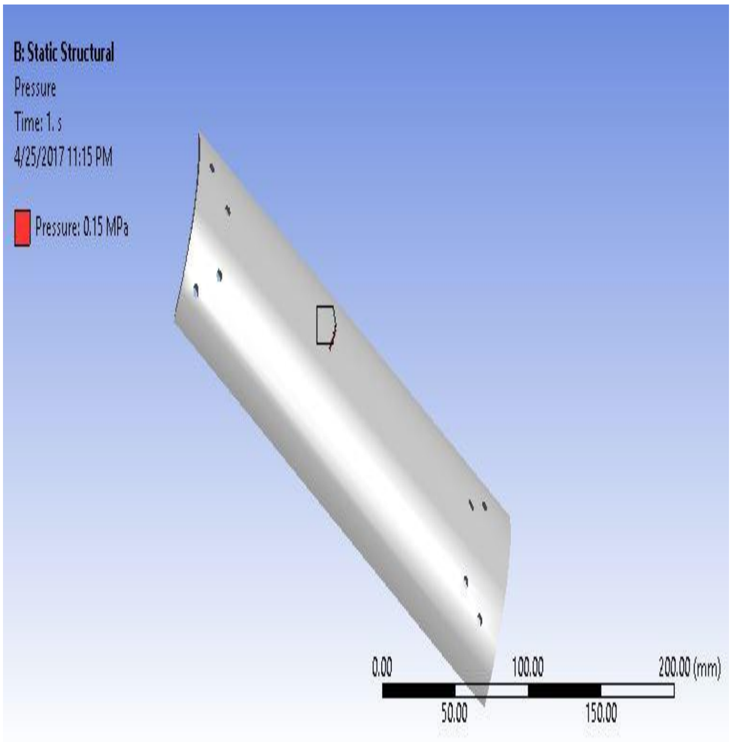
7.1.2 Working Analysis of Wind Power Generation Unit:

For analyzing the performance of the wind power generation unit, the same procedure carried out for assessing the solar unit is followed. In the first hour, the turbine is made to rotate and generate power and, in the next hour, the battery is completely discharged. This procedure is repeated and the values of power generated for each respective hour are noted down. This data is represented along with the solar data in the form of a bar chart (Fig 6.2).

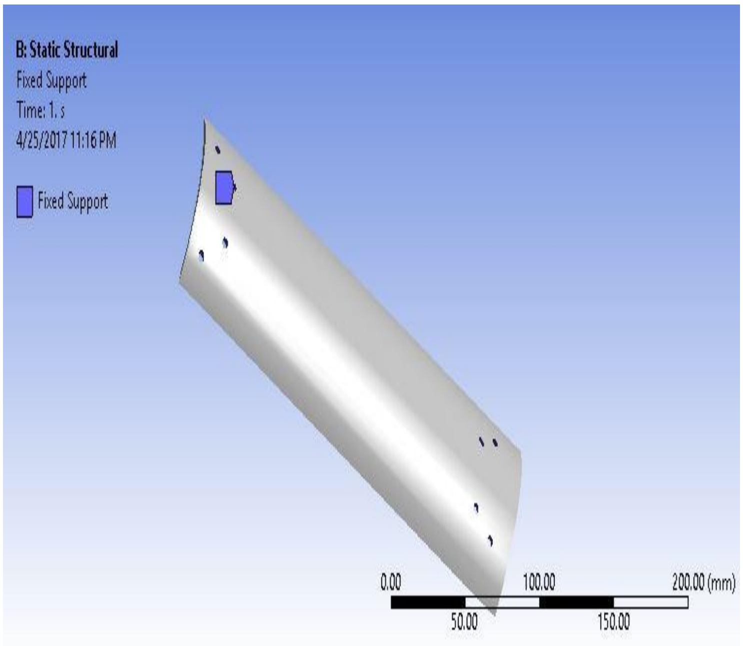
In this way, analysis has been done upon both systems and the outcomes have been combined in order to compare the availability and efficiency of each source in that particular area.

8.2 Analysis of VAWT Blade using ANSYS:

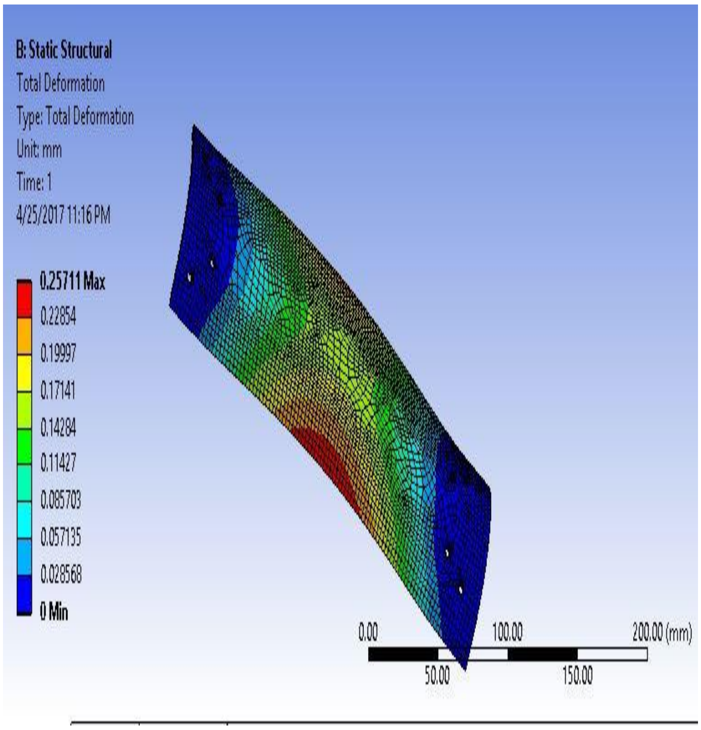
Analysis has been carried out for the blades of the Vertical Axis Wind Turbine using ANSYS. Following are the results obtained:



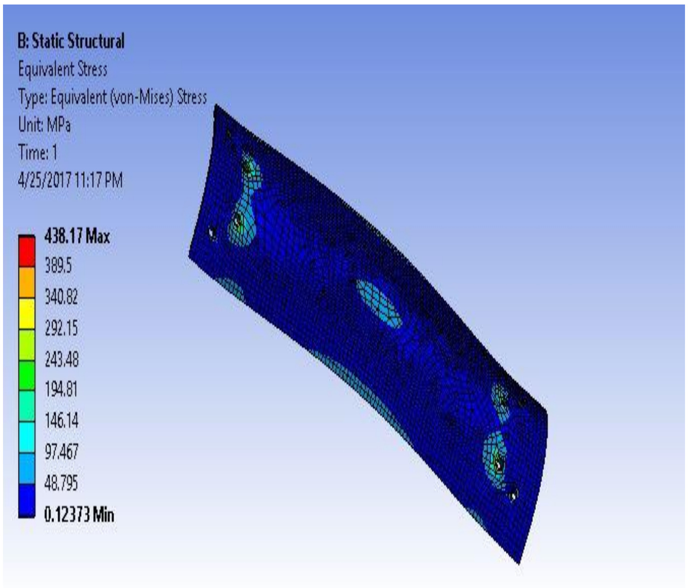
APPLICATION OF A PRESSURE OF MAGNITUDE 0.15MPA UPON THE BLADE



ANALYSIS UNDER FIXED SUPPORT CONDITION



NODAL SOLUTION FOR TOTAL DEFORMATION HAVING MAXIMUM VALUE OF LOAD AT 0.25711



NODAL SOLUTION FOR VON-MISES STRESS WITH THE MAXIMUM VALUE BEING AT 438.17 MPa

CHAPTER – 8

Conclusion:

Some of the aspects of Hybrid Power Generation System which make it special are:

1. It uses a combination of two sources. So, one source can compensate the absence of other source and continue generating power.
2. There is less scope for an abrupt halt in power generation.
3. It is very eco-friendly and highly sustainable.
4. This system requires comparatively less investment and hence, is very economical.
5. Can play a very decisive role in the quest to reduce carbon footprint.
6. This system is quite useful for backward, rural areas which face severe shortage of electricity but have abundant solar and wind energy.
7. It is easy to transport and install this system.
8. The working mechanism is not very complicated.
9. Maintenance of maximum irradiance and constant power generation due to solar tracking system.
10. It has several applications in farming sector.
11. This system can also be installed atop buildings so as to meet the minor power requirements.

Hence, due to all these features, Hybrid Power Generation System can be considered as a capable alternative to replace the existing conventional power generation systems in order to be both eco-friendly and efficient.

8.4 REFERENCES:

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ANNEXURE- I

Project Outcomes:

Following are the project outcomes which we have fulfilled:

PO1.Engineering Knowledge:

Engineering knowledge of areas such as Solar Energy, Wind Energy and Electricity has been applied in order to couple both Solar and Wind Power systems and obtain a single unit.

PO2. Problem analysis:

The main problem in today's power generation systems is the availability of a single source. When this sole source's availability is limited or almost nil, it could lead to severe shortage of power. This was the problem that was analyzed while developing the project.

PO3. Design/Development of Solutions:

The above mentioned problem was analyzed and its solution was found in the form of a dual system having a combination of both solar and wind power generation units i.e. the Hybrid Wind power Generation System.

The Hybrid Power Generation System uses the sophisticated technology of Solar Tracking. This is done in order to ensure continuous irradiance and constant power generation throughout the day.

PO6. The Engineer and Society:

This system is quite beneficial to the society due to its minimal cost and favorable electricity generation. It can be easily installed at any place. For example, its services could be used in rural areas in order to overcome the electricity shortage in such areas.

PO7. Environment and Sustainability:

This power generation system relies upon renewable energies and hence is quite environment-friendly. Also, due to the presence of two sources (Sun and Wind) for power generation, it stands out to be a very sustainable method.

PO9. Individual and Team Work:

Effective work by each individual of the team, both on individual basis and team basis, in order to complete the project by the prescribed time.

PO10. Communication:

Knowledge was procured from various sources for this project. Especially, communication between the team members and that of the team members with the project guide proved to be very effective.

PO11. Project Management and Finance:

Along with the engineering aspect, the team also framed a financial model for the project. This model was followed by the team in order to have a regulated expenditure and also to complete the project as per the schedule.

PO12. Life-Long Learning:

There is a vast scope for this system in various areas. As of now, its use is limited to only some select areas. Therefore, the aim is to spread information regarding this system everywhere in order to help tackle issues due to present power generation techniques and provide an eco-friendly solution.

ANNEXURE- II

Project Management Details:

Shown below in the figure is the sequence of works carried out by the team in order to complete the project by the prescribed time. Starting from the initial step i.e. Project Selection, the sequence of operations and the time at which each and every operation has been carried out.