HYBRID POWER GENERATION SYSTEM BY USING WIND-SOLAR PHOTOVOLTAIC

A thesis report submitted to the department of mechanical engineering for the partial fulfillment of the degree of Bachelor of Science in Mechanical Engineering

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APPROVAL

This is to certify that the project on **"HYBRID POWER GENERATION SYSTEM BY USING WIND-SOLAR PHOTOVOLTAIC"** By Md.Abdul Malak (BME-1601008108) Md. Parvez Sarker (BME1601008004) Shahadat Hossain (BME-1601008022) has been carried out under our supervision. The project has been carried out in partial fulfillment of the requirements of the degree of Bachelor of Science (B.Sc.) in Mechanical Engineering of years of 2019 and has been approved as to its style and contents.

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DECLERATION

We, hereby, declare that the work presented in this Thesis, is the outcome of the research work performed by us under the honorable teacher of Lecturer, Department of Mechanical Engineering, Sonargaon University.

We also declare that no part of this thesis and thereof has been or is being submitted elsewhere for the award of any degree or Diploma.

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ABSTRACT

Renewable energy sources i.e., energy generated from solar, wind, biomass, hydro power, geothermal and ocean resources are considered as a technological option for generating clean energy. But the energy generated from solar and wind is much less than the production by fossil fuels, however, electricity generation by utilizing PV cells and wind turbine increased rapidly in recent years. This paper presents the Solar-Wind Hybrid Power system that harnesses the renewable energies in Sun and Wind to generate electricity. System control relies mainly on micro controller. It ensures the optimum utilization of resources and hence improves the efficiency as compared with their individual mode of generation. Also it increases the reliability and reduces the dependence on one single source. This hybrid solar-wind power generating system is suitable for industries and also domestic areas.

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1.1 Introduction

We all know that the world is facing a major threat of fast depletion of the fossil fuel Reserves. Most of the present energy demand is met by fossil and nuclear power plants. A small part is met by renewable energy technologies such as the wind, solar, biomass, geothermal etc. There will soon be a time when we will face a severe fuel shortage. As per the law of conservation of energy, “Energy can neither be created, nor be destroyed, but it can only be converted from one form to another”. Most of the research now is about how to conserve the energy and how to utilize the energy in a better way. Research has also been into the development of reliable and robust systems to harness energy from nonconventional energy resources. Among them, the wind and solar power sources have experienced a remarkably rapid growth in the past 10 years. Both are pollution free sources of abundant power. By adopting the appropriate technology for the concerned geographical location, we can extract a large amount of power from solar radiations. More over solar energy is expected to bathe most promising alternate source of energy. Generators which are often used as an alternative to conventional power supply systems are known to be run only during certain hours of the day, and the cost of fueling them is increasingly becoming difficult if they are to be used for commercial purposes. Wind energy is the kinetic energy associated with the movement of atmospheric air. Wind energy systems for irrigation and milling have been in use since ancient times and at the beginning of the 20th century it is being used to generate electric power. Windmills for water pumping have been installed in many countries particularly in the rural areas. Wind turbines transform the energy in the wind into mechanical power, which can then be used directly for grinding etc. or further converting to electric power to generate electricity. Wind turbines can be used singly or in clusters called ’wind farms. There is a growing awareness that renewable energy such as photovoltaic system and Wind power have an important role to play in order to save the situation. Hybrid power system consist of a combination of renewable energy source such as wind generators, solar etc. of charge batteries and provide power to meet the energy demand, considering the local geography and other details of the place of installation. These types of systems are not connected to the main utility grid. They are also used in stand-alone applications and operate independently and reliably. The best application for these type of systems is in remote places, such as rural villages, in telecommunications etc. The importance of hybrid systems has grown as they appear to be the right solution for a clean and distributed energy production. This paper presents the Solar-Wind Hybrid Power system that harnesses the renewable energies in Sun and Wind to generate and supply electricity to a private house, house depending on the farm house, a small company, an educational institution or an apartment need at the site where used.

1.2 Literature review

The need for renewable energy sources stems from the recognition of the finite supply of fossil fuels, rising cost of fossil fuels, and the pollution caused by fossil fuels. Despite these issues, fossil fuels still dominate the energy market, accounting for over 80% of energy production globally. Both the physical environment and the social environment are greatly impacted by the consumption and production of energy from fossil fuels. Overwhelming evidence supports the fact that production and use of fossil fuels is unsustainable and has major environmental costs. (Hedberg 2010). Fossil fuels are a limited nonrenewable resource and experts predict that within the next few centuries most will be depleted. In addition to a diminishing supply, fossil fuels face the problem of damage to the environment. A leading cause of climate change is the accumulation of carbon dioxide in the atmosphere from the burning of fossil fuels (Mostafaeipour 2011). Energy derived from fossil fuel is both limited and nonrenewable which means that these energy resources are becoming more scarce and expensive (Rahim et al. 2012). Despite the increase in scarcity and expense, the global demand for energy will continue to rise. “It is expected that worldwide primary energy demand will increase by 45%, and demand for electricity will increase by 80% between 2006 and 2030” (Santos-Almelo’s et al.
2012). In developed countries there is an expected 1% annual energy growth rate 5 and an expected 5% annual energy growth rate for developing countries (Rahim et al. 2012). One of the major energy risks that civilization faces is peak fossil fuel. Peak fossil fuel refers to fossil fuel production increasing to a peak and then gradually declining to where it can no longer meet demand. Demand will only be met at prices that are too high to meet the wide spread fossil fuel use that is currently observed today (Leggett and Ball 2012). Research done by Leggett and Ball (2012) indicate that all fuel types except for coal are expected to peak before 2030 with an average of 2028. Rahim et al explain that “when global energy production is primarily and continuously dominated by fossil fuels, an energy crisis will occur in the future” (Rahim et al. 2012).The current figures show that wind and solar have the ability to completely replace fossil fuel use as early as 2024, if the growth trajectory of wind and solar continues to follow the growth rate of the mobile phone/China Expressway system (Leggett and Ball 2012).The pervious statistic is derived from comparing the adoption of renewable energy to the adoption rate of another technology. Renewable energy sources are going to have to be explored and implemented. Currently renewable energy sources such as biomass, hydro, solar, and wind are the most viable alternative to conventional fossil fuel use (Lovejoy 1996). There is substantial literature on renewable energy sources and support for increasing implementation of renewable energy methods. There is a consensus that renewable energy alternatives are the only answer to ensure a long term energy solution. Renewable energy leaves future generations with a non-depleting energy source as well as a healthier environment.

1.3 Objectives

There were many objectives of this thesis project as input was received from many engineering activities within
Electrical Power generation by the Solar Power PV Hybrid Power Generation System.
The objectives are as flows:

- To produces Electrical Energy.
- To pollution free earthling system.
- To improve solar energy system.
- To improve hybrid power energy system.

Chapter 2 Literature Review

2.1 Hybrid Power System

Hybrid power systems are designed for the generation and use of electrical power. They are most cases independent of the large centralized electrical grid and in-cooperate more than one power source. This system may range from a number of megawatts to individual household power supplies of 1 kW. They deliver alternating current at a fixed frequency and observe the voltage variation of plus or minus 6%. Usually has a major control system which enables the system to supply electricity in the required quality. A "hybrid" electric system that combines wind and solar technologies offers several advantages over either single system. Even during the same day, in many regions worldwide, there are different and opposite wind and solar resource patterns. Where power is to be transported over long distances the power may be transformed to higher voltages to minimize losses but rarely is this the case. Inverters and battery systems are applied for frequency and voltage stabilization in small systems of less than 100 kW. Such a system is found on Magenta Island in Lake Victoria, Kenya.Hybrid solar PV and wind generation system become very attractive solution in particular for stand-alone applications. Combining the two sources of solar and wind can provide better reliability and their hybrid system becomes more economical to run since the weakness of one system can be complemented by the strength of the other one. The integration of hybrid solar and wind power systems into the grid can further help in improving the overall economy and reliability of renewable power generation to supply its load. Similarly, the integration of hybrid solar and wind power in a stand-alone system can reduce the size of energy storage needed to supply continuous power. Solar electricity generation systems use either photovoltaic's or concentrated solar power. The focus in this paper will be on the photovoltaic's type. Detailed descriptions of the different technologies, physics and basics of PV can be found in many textbooks and papers such as [4-7]. Kurtz [8] pointed out that ten years ago the concentrator cell was only ~30% efficient compared with more than 40% today with the potential to approach 50% in the coming years. Si cells have efficiencies of 26% and multi-junction III-V-compound cells have efficiencies above 45% (48% in the laboratory) as pointed out in reference [9]. PV modules produce outputs that are determined mainly by the level of incident radiation. As the light intensity increases, photocurrent will be increased and the open-circuit voltage will be reduced [10]. The efficiency of any photovoltaic cell decreases with the increasing temperature which is non-uniformly distributed across the cell [11]. The solar output power can be smoothed by the distribution of solar power in different geographical areas [12]. Electricity from solar PV and concentrated solar power plants is significantly expensive and requires significant drop in cost or change in policies by either subsidizing or forcing the use of these technologies to be able to achieve significant market penetration [13]. Global wind report (2012) indicated that the annual market grew by around 10% to reach around 45 GW and the cumulative market growth was almost 19% [14]. Detailed descriptions of the wind energy can be found in references [4] and [15]. Wind turbines (WTs) are classified into two types: horizontal-axis WT (HAWT) and vertical-axis WT (VAWT). The highest achievable extraction of power by a WT is 59% of the total theoretical wind power [15]. Hybrid solar-wind systems can be classified into two types: grid connected and stand-alone. Literature reviews for hybrid grid Connected and stand-alone solar PV and wind energies were conducted worldwide by many researchers who have presented various challenges and proposed several possible solutions. Due to the nature of hybrid solar PV and wind energies, optimization techniques can play a good role in utilizing them efficiently. Graphic construction methods [16], linear programming [17-18], and probabilistic approach [19] are few examples of optimization techniques that have been developed for techno-economically optimum hybrid renewable energy system for both types. Luna-Rubio et al. [20] conducted a review of existing research of optimal sizing of renewable hybrids energy systems with energy storage components for both stand-alone and grid-connected systems. The authors gave brief descriptions about those indicators and the different sizing methods. A review of control strategies for a hybrid renewable energy system was carried out in [21] and another review was done in [22] for optimization of hybrid renewable energy system with more focus on wind and solar PV systems. The reviews in [21] and [22] are applicable for both types; grid-connectedandstand-alonesystems.

2.2 Implementation of Hybrid Energy System

Intermittent energy resources and energy resources unbalance are the most important reason to install a hybrid energy supply system. The Solar PV wind hybrid system suits to conditions where sunlight and wind has seasonal shifts. As the wind does not blow throughout the day and the sun does not shine for the entire day, using a single source will not be a suitable choice. A hybrid arrangement of combining the power harnessed from both the wind and the sun and stored in a battery can be a much more reliable and realistic power source. The load can still be powered using the stored energy in the batteries even when there is no sun or wind. Hybrid systems are usually built for design of systems with lowest possible cost and also with maximum reliability. The high cost of solar PV cells makes it less competent for larger capacity designs. This is where the wind turbine comes into the picture, the main feature being its cheap cost as compared to the PV cells. Battery system is needed to store solar and wind energy produced during the day time. During night time, the presence of wind is an added advantage, which increases the reliability of the system. In the monsoon seasons, the effect of sun is less at the site and thus it is apt to use a hybrid wind solar system. The system components are as follows.

2.3 Solar Energy

The sun is the largest energy source of life at the same time, it is the ultimate source of all energy (except power of geothermal). The sun radiates 174 trillion kWh of energy to the earth per hour. In other words, the earth receives 1.74 x 10 17 watts of power from the sun (Breeze P., 2009). Characteristics of the sun is simplified as follows : mass 2× kg, beam length 700.000 km, age 5× years and estimated roughly 5 billion more years of life. The surface temperature of sun is approximately 5800 K while the internal temperature is approximately 15.000.000 K. High temperature reactions is due to the transformation of hydrogen in helium. The process of the nuclear fusion, which is characterized from the following reaction. Energy, is the result of the sun high temperature and the large amounts of energy emitted continuously. It is calculated that for each gram of hydrogen, that is converted to He, sun radiates energy equal with U= 1.67× kWh. The solar energy is emitted to the universe mainly by electromagnetic radiation. (SAO, 2014) The estimated distance from the sun is
150,000,000 km while the sun is stationed and spins around by the earth in an elliptic orbit. The light having the travelling speed of 300,000 km/sec to overcome the aforesaid distance, it consumed approximately 8.5 minutes. Actinic of emitted radiation is removed by the aster to the space and the intensity of radiation J, is calculated by the is presenting the electromagnetic radiation power and d is presenting the distance from the sun. It is estimated that one-third of the radiation is reflected back. The rest of energy will be absorbed and retransmitted to the space while the earth reradiates just as energy as it receives and creates a balance of energy balance at the level of temperature which is suitable for life. Solar energy can be used to generate electricity directly with the photovoltaic panels.

2.4 How PV Cells Generate Electricity

Under the sun, a photovoltaic cell acts as a photosensitive diode that instantaneously converts light – but not heat – into electricity. Photovoltaics (PV) or solar cells as they are often called are semiconductor devices that convert
sunlight into direct current (DC) electricity. Groups of PV cells are electrically configured into modules and arrays, which can be used to charge batteries, operate motors, and to power any number of electrical loads. With the appropriate power conversion equipment, PV systems can produce alternating current (AC) compatible with any conventional appliances, and can operate in parallel with, and interconnected to, the utility grid.

2.5 Cell Layers

A top, phosphorus-diffused silicon layer carries free electrons – un-anchored particles with negative charges. A thicker, boron doped bottom layer contains holes, or absences of electrons, that also can move freely. In effect, precise manufacturing has instilled an electronic imbalance between the two layers.

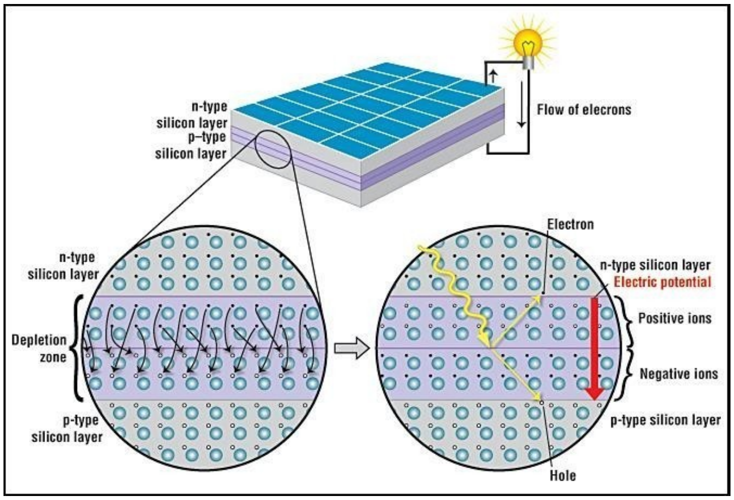


Figure: 2.1 Cell Layers

2.6 Sun Activation

Photons bombard and penetrate the cell and activate electrons, knocking them loose in both silicon layers. Some electrons in the bottom layer sling-shot to the top of the cell. These electrons flow into the metal contacts as electricity, moving into a circuit through an n-cell module. Electrons flow back into the cell via a solid contact layer at the bottom creating closed loop or circuit. The solar cell is the basic building of the PV power system and it produces about 1 W of power. To obtain high power, a great number of such cells are connected in series and parallel circuits on a panel, also known as a module. The solar array is a group of a several modules electrically connected in series parallel combination to generate the required current and voltage

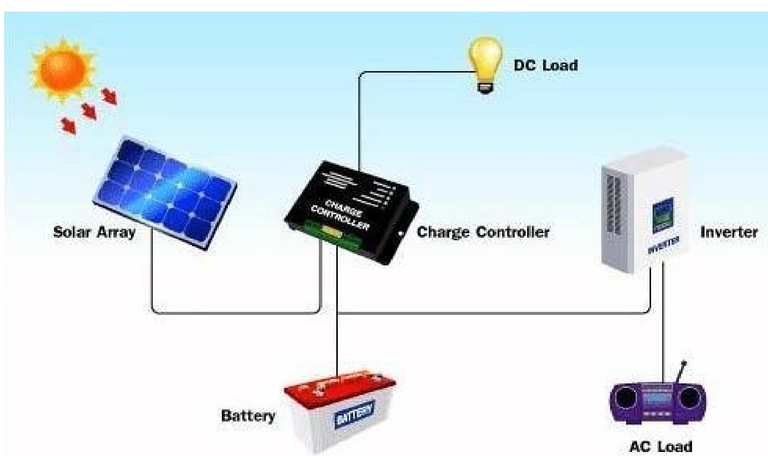


Figure: 2.2 Sun Activation

2.7 Components of a PV Array

A photovoltaic array consists of multiple photovoltaic modules, casually referred to as solar panels, to convert solar radiation into usable direct current electricity. A photovoltaic system for residential, commercial, or industrial energy supply normally contains an array of photovoltaic (PV) modules, one or more inverter, a tracking system, electrical wiring and interconnections, and mounting for other components. A photovoltaic system may include any or all of the following: renewable energy credit revenue-grade meter, maximum power point tracker (MPPT), battery system and charger, GPS solar tracker, energy management software, solar concentrators, solar irradiance sensors. The number of modules in the system determines the total DC watts capable of being generated by the solar array; however, the inverter is what governs the amount of AC watts that can be distributed for consumption. This means that the rating of the inverter determines the available AC watts available for use by the consumer.

Figure: 2.3 Components of a PV Array

2.8 Photovoltaic Structure

The photovoltaic cells structure is quite straightforward. It consists of 6 different layers of materials as shown in Figure 2.1. First of all, the efficiency of photons absorption is increasing due to the assistance of black cover glass surface, the glass is protecting the cell from the elements of atmosphere. The reflection losses of the photons are reduced to less than 5% by the anti-reflective coating. The travelling distance of the Photons was minimized by contact grid, so that it able to reach the semiconductors. The heart of the photovoltaic system is consisting of semiconductors p and n in the form of two thin layers. Lastly, the back contact is contributing for the better conduction.

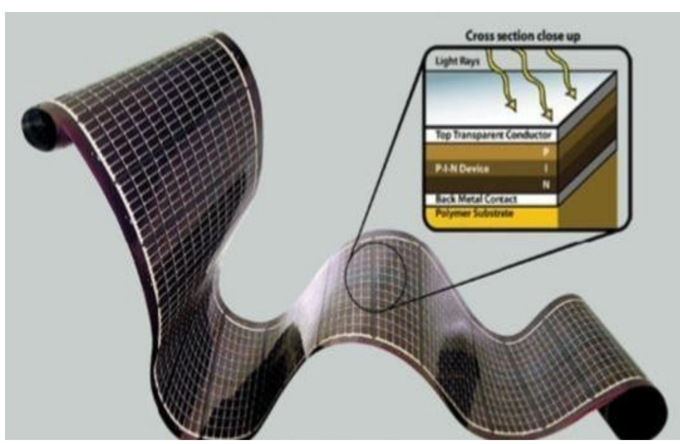


Figure: 2.4 Photovoltaic Structures

2.9 Photovoltaic Solar Power

Solar panels are the medium to convert solar energy into the electrical energy. Solar panels can convert the energy directly or heat the water with the induced energy. PV (Photo-voltaic) cells are made up from semiconductor structures as in the computer technologies. Sun rays are absorbed with this material and electrons are emitted from the atoms.This release activates a current. Photovoltaic is known as the process between radiation absorbed and the electricity induced. Solar power is converted into the electric power by a common principle called photo electric effect. The solar cell array or panel consists of an appropriate number of solar cell modules connected in series or parallel based on the required current and voltage

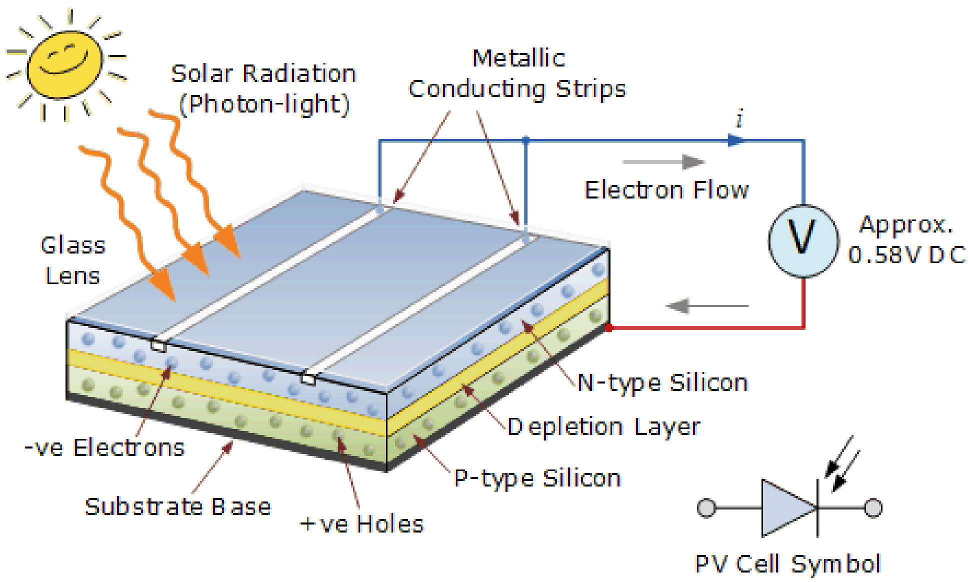


Figure: 2.5 Photovoltaic Solar Powers.

Chapter 3 Methodology

3.1 Wind Energy

The energy of wind converted into useful form (usually electric current) is called wind energy". Wind energy is a Renewable energy source. Once used can be replaced. Wind energy is the kinetic energy of air in motion, also called wind. Total wind energy flowing through an imaginary surface with area A during the time t is: where ρ is the density of air; v is the wind speed; Avt is the volume of air passing through A (which is considered perpendicular to the direction of the wind); Avtρ is therefore the mass m passing through "A". Note that ½ ρv^2 is the kinetic energy of the moving air per unit volume. Power is energy per unit time, so the wind power incident on A (e.g. equal to the rotor area of a wind turbine) is: Wind power in an open air stream is thus proportional to the third power of the wind speed; the available power increases eightfold when the wind speed doubles. Wind turbines for grid electric power therefore need to be especially efficient at greater wind speeds. Wind is the movement of air across the surface of the Earth, affected by areas of high pressure and of low pressure. The global wind kinetic energy averaged approximately 1.50 MJ/m^2 over the period from 1979 to 2010, 1.31 MJ/m^2 in the Northern Hemisphere with 1.70 MJ/m^2 in the Southern Hemisphere. The atmosphere acts as a thermal engine, absorbing heat at higher temperatures, releasing heat at lower temperatures. The process is responsible for production of wind kinetic energy at a rate of 2.46 W/m^2 sustaining thus the circulation of the atmosphere against frictional dissipation. Through wind resource assessment it is possible to provide estimates of wind power potential globally, by country or region, or for a specific site. A global assessment of wind power potential is available via the Global Wind Atlas provided by the Technical University of Denmark in partnership with the World Bank. Unlike 'static' wind resource atlases which average estimates of wind speed and power density across multiple years, tools such as provide time-varying simulations of wind speed and power output from different wind turbine models at an hourly resolution. More detailed, site specific assessments of wind resource potential can be obtained from specialist commercial providers, and many of the larger wind developers will maintain in-house modeling capabilities. The total amount of economically extractable power available from the wind is considerably more than present human power use from all sources. Axel Kleidon of the Max Planck Institute in Germany carried out a "top down" calculation on how much wind energy there is, starting with the incoming solar radiation that drives the winds by creating temperature differences in the atmosphere. He concluded that somewhere between 18 TW and 68 TW could be extracted. Cristina Archer and Mark Z. Jacobson presented a "bottom-up" estimate, which unlike Kleidon's are based on actual measurements of wind speeds, and found that there is 1700 TW of wind power at an altitude of 100 meters over land and sea. Of this, "between 72 and 170 TW could be extracted in a practical and cost-competitive manner". The strength of wind varies, and an average value for a given location does not alone indicate the amount of energy a wind turbine could produce there. To assess prospective wind power sites a probability distribution function is often fit to the observed wind speed data. Different locations will have different wind speed distributions. The Weibull model closely mirrors the actual distribution of hourly/ten-minute wind speeds at many locations. The Weibull factor is often close to 2 and therefore a Rayleigh distribution can be used as a less accurate, but simpler model.

3.2 The Wind

Wind is the continuous movement of atmospheric air masses and is determined by its speed and orientation. This movement derives from the changes and the different values of the atmospheric pressure while these values are the result of the solar heating of different parts of the earth's surface. Despite the fact that the atmospheric air moves horizontally and vertically as well, only its horizontal movement is actually considered as wind. (Breeze, 2009). The wind energy derives from the air as a result of its movement which is depicted in Figure 2.6. Wind energy is the conversion of a small percentage, about 0.2%, of the solar radiation that reaches the surface of the earth. The wind power around the globe is estimated in 3.6×109 MW while, according to valid estimations of the world meteorology organization, the percentage which is available for energy exploitation in various parts of the world is only 1% and it is estimated around 0.6Q (175×1012

KWh). (Manwell and McGowan, 2009)

3.3 Wind Power

The wind energy is a renewable source of energy. Wind turbines are used to convert the wind power into electric power. Electric generator inside the turbine converts the mechanical power into the electric power. Wind turbine systems are available ranging from 50W to 3-4 MW. The energy production by wind turbines depends on the wind velocity acting on the turbine. Wind power is able to feed both energy production and demand in the rural areas. It is used to run a windmill which in turn drives a wind generator or wind turbine to produce electricity

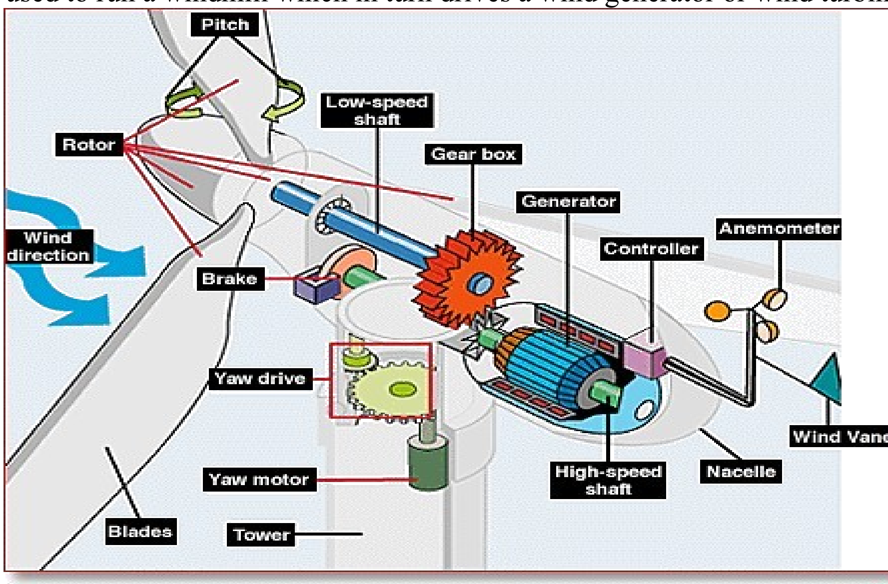


Figure: 3.2 Wind Power

Wind turbines work by converting the kinetic energy in the wind, first to rotational kinetic energy in the turbine and then electrical energy that can be supplied via the national grid. The energy available for conversion mainly depends on the wind speed and swept area of the turbine. Wind turbines are available in various sizes from a large number of wind turbine manufacturers, agents and developers. The wind profile and wind speed at specific site need to be evaluated to identify which turbine is suitable for the particular site condition.

As the wind turbine itself may be as much as 70% of the total project cost it is vital that it produces optimal electricity for the site. For low wind speed locations different modifications of turbines might be available. A German physicist Albert Betz concluded, no wind turbine can convert more than 16/27 (59%) of the kinetic energy of the wind into mechanical energy turning a rotor. The theoretical maximum power efficiency of any design of wind turbine is 0.59. (i.e. no more than 59% of the energy carried by the wind can be extracted by a wind turbine.) This is called “maximum power coefficient”: $C_{p\,max} = 0.59$

In practice, wind turbine rotors deliver much less than the Betz limit. The efficiency of a turbine depends on different factors such as the turbine rotor, transmission train and the electrical generator. Normally the commercial turbine rotors have aerodynamic efficiencies in real conditions (power coefficients) which vary from 30% to 50%. Gearbox and generator efficiencies can be estimated to be around 80% to 95% depending on size and quality of production. Efficiency of turbine is not constant. It is a function of the wind speed. Many companies do not provide their wind turbine efficiencies rather the power curve of wind turbine is provided. The power curve of a wind turbine is a graph that represents the turbine power output at different wind speeds values. The power curve is normally provided by the turbine’s manufacture. Figure 3.2 presents an example of a wind turbine power curve.

3.4 Wind Power Generation

Wind power systems convert the kinetic energy of the wind into other forms of energy such as electricity. Although wind energy conversion is relatively simple in concept, turbine design can be quite complex. Most commercially available wind turbine uses a horizontal – axis configuration (HAWT) with two or three blades, a drive train including a gearbox and a Generator and a tower to support the rotor [3]. Typical sizes for a wind turbine range from 200-750
KW with electricity produce within a specific range of wind speed. Cooperative research done by manufacturing companies is aimed at increasing the aerodynamics efficiency and structural strength of wind turbine blades, developing variable speed generation and electronic power controls and using taller tower that allow access to the stronger wind found at greater height. An important factor in how much power your wind turbine will produce is the height of it's tower. The power available in the wind is proportional to the cube of its speed. This means that if wind speed doubles, the power available to the wind generator increases by a factor of 8. Since wind speed increases with height an increase in the tower height can mean enormous increase in the amount of electricity generated by a wind turbine. Figure 2.2 shows the relationship between height above ground and wind power.

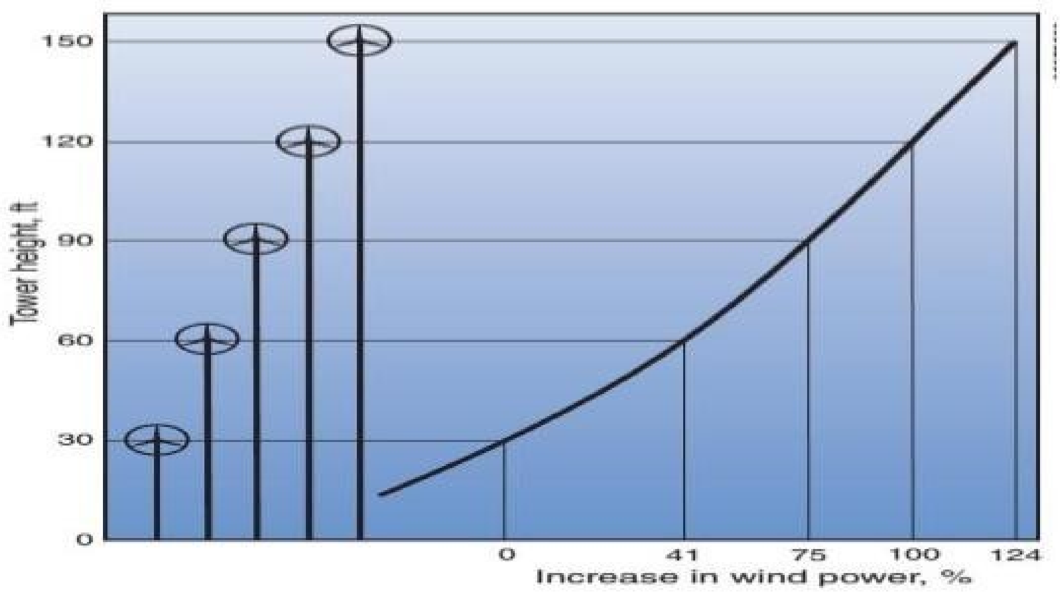


Figure 3.3 Wind Power Generations

3.5 Wind Speed Increases with Height

The fundamental equation governing the mechanical power capture of the wind turbine rotor blades, which drives the electrical generator, is given by equation. The theoretical maximum value of the power coefficient p is 0.59 (Betz Limit) and it is often expressed as function of the rotor tip-speed to wind-speed ratio (TSR). Whatever maximum value is attainable with a given wind turbine, it must be maintained constant at that value for the efficient capture of maximum wind power.

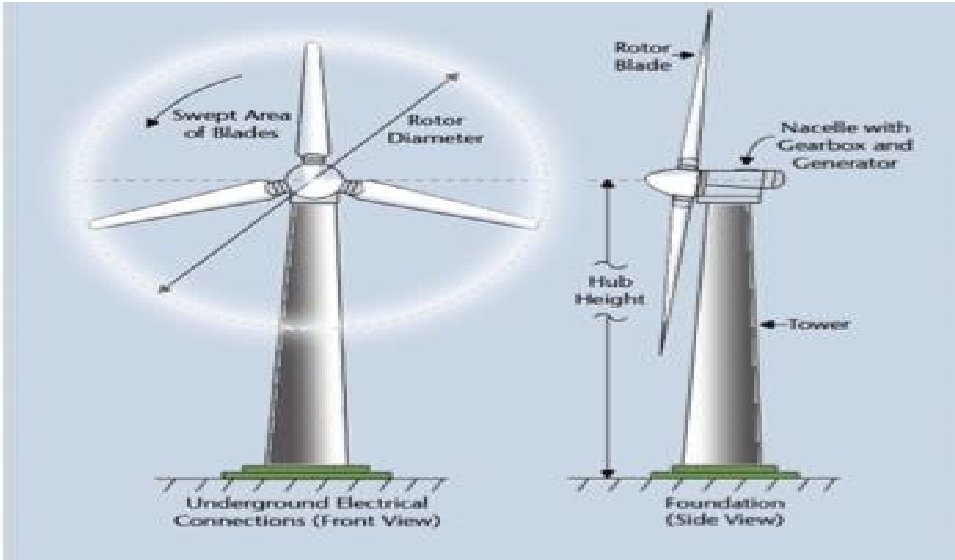


Figure: 3.4 Wind Speed Increases with Height

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

Where = air density (kg/m3)
A = area swept of rotor (m2)
V = wind speed (m/s)
If wind speed is between the rated wind speed and the furling speed of the wind turbine, the power output will be equal to the rated power of the turbine. Finally, if the wind speed is less than the cut-in speed or greater than the furling speed there will be no output power from the turbine. Power output from practical turbine; the fraction of power extracted from the power in the wind by a practical wind turbine is usually given the symbol p, standing for the coefficient of performance. Using this notation, the actual mechanical power output can be given by equation

3.6 Power Control of Wind Turbines

Wind turbines are designed to produce electrical energy as cheaply as possible. Wind turbines are therefore generally designed so that they yield maximum output at wind speeds around 15 meters per second. (30 knots or 33 mph). It's does not pay to design turbines that maximize their output at stronger winds, because such strong winds are rare. In case of stronger winds, it is necessary to waste part of the excess energy of the wind in order to avoid damaging the wind turbine.

3.7 Batteries

The batteries in the system provide to store the electricity that is generated from the wind or the solar power. Any required capacity can be obtained by serial or parallel connections of the batteries. The battery that provides the most advantageous operation in the solar and wind power systems are maintenance free dry type and utilizes the special electrolytes. These batteries provide a perfect performance for long discharges.

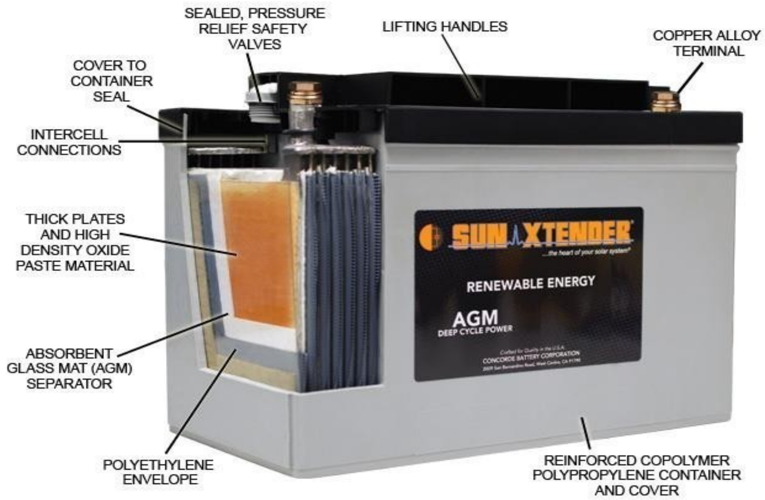


Figure: 3.5 Batteries

3.8 Inverter

Energy stored in the battery is drawn by electrical loads through the inverter, which converts DC power into AC power. The inverter has in-built protection for Short-Circuit; Reverse Polarity, Low Battery Voltage and Over Load.

Figure: 3.6 Inverter

3.9 Rectifier

Rectifiers are used to convert the AC power from the wind turbine to DC power to be used in the charging of batteries and supplying DC loads [4]. These are normally in cooperated in the wind turbines designed for off-grid operation.

3.10 Solar Cleaning Wiper

At large-scale solar plants, keeping the surfaces of solar panels free from dust, sand and bird droppings is not just a matter of finicky housekeeping. It can be a matter of plant profitability. Dirty panels lower power generation efficiencies. Bird droppings on panels, for example, block the sunlight. A Tokyo-based company has a solution. Sinfonia Technology announced late last month that it has developed a robot with camera and sensors that can move autonomously and clean solar panels at large-scale solar power plants. Sinfonia's robot has a distinction in being "autonomous" in that, rather than tethered to rails, the robot is able to move from panel to panel, to tackle the panels' dirt and debris. The robot is equipped with scrub brush, wiper and detergent; and also sprinkles water stored in its tank. The robot can work in the dark; it has LEDs, having wavelengths in the infrared range.

Figure: 3.7 Solar Cleaning Wipe

3.11 Solar Reflector

Flat-roofed urban buildings bake in the sun all day with no shade from trees, so they are the perfect place for solar panels. They can deliver power directly to where it's needed without significant transmission loss. But roof space is limited so efficiency is very important.

Tank Solar of Minneapolis has developed a system that achieves amazing efficiencies on flat roofs by putting thin-film reflectors in the spaces between the tilted solar panels. To make this work, they had to rethink the way solar cells are interconnected: Conventional solar systems connect panels with a series string and just like the old Christmas lights, the whole string goes dark if a single light is bad. Series connected solar cells have the same problem and worse: A tree or cloud shadow, a fallen leaf, or blob of bird poop can reduce the output of the whole string. If the cells are not matched and equally illuminated, efficiency drops significantly. Tank has solved this problem by designing an entirely unique PV module. They install six DC-DC converters in each solar panel that connect to the solar cells in a unique series/parallel arrangement that provides full output even when there are voltage differences or even failures. This unique cell connection method makes it possible to reduce the spacing between rows of solar panels, which are angled towards the sun. Shadows from the next row no longer degrade the whole system as they do with series connection so the tilt angle of the panels can be increased. The higher tilt allows rain to better clean the panels, reducing the need for cleaning as well.

Figure 3.8 Figures Solar Reflector

3.12 DC Motor

A direct current or DC motor, converts electrical energy into mechanical energy. It is one of two basic types of motors: the other type is the alternating current or AC motor. Among DC motors, there are shunt-wound, series- wound, compound-wound and permanent magnet motors. A motor is an electrical machine which converts electrical energy into mechanical energy. The principle of working of a DC motor is that "whenever a current carrying conductor is placed in a magnetic field, it experiences a mechanical force". The direction of this force is given by Fleming's left hand rule and it's magnitude is given by F = BIL. Where, B = magnetic flux density, I = current and L = length of the conductor within the magnetic field.

Figure: 2.4 DC Motor

3.13 Charge Controllers

Charge controllers are used to prevent the batteries from getting overcharged or over drained in order to extend their lifetime operation. They also regulate the rate of charging and discharging of a battery bank and maintain it within a predetermined rate. A wind charge controller is different in design to the solar charge controller in that it switches from charging the batteries when full to the dump load. This is because a wind turbine has to constantly be on load to avoid over spinning and getting damaged due to high centrifugal forces. On the other hand, a solar charge controller simply isolates the PV array from the batteries when full.

Figure: 3.10 Charge Controllers

3.14 Solar-Wind Power System

Solar-Wind Hybrid Power system is the combined power generating system by wind mill and solar energy panel. It also includes a battery which is used to store the energy generated from both the sources. Using this system power generation by windmill when wind source is available and generation from PV module when light radiation is available can be achieved. Both units can be generated power when both sources are available.

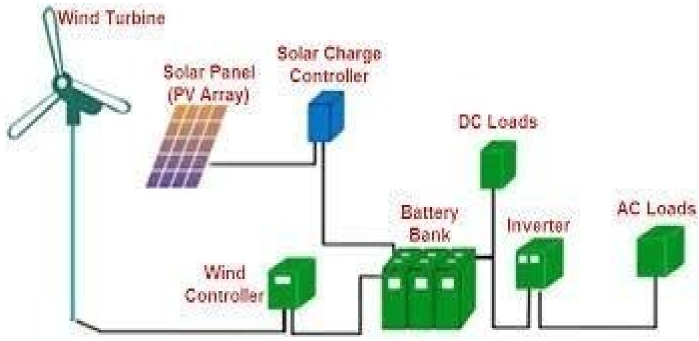


Figure: 3.11 solar wind block diagram

3.15 Wind Power

Energy available in wind is basically the kinetic energy of large masses of air moving over the earth surface. Blades of the wind turbine receive this kinetic energy, which is then transformed to useful mechanical energy, which is then transformed further to mechanical or electrical energy depending on the end use. A wind rotor of cross sectional area A in m2 is exposed to wind stream with velocity V in m/s as depicted in figure 3.1 below.

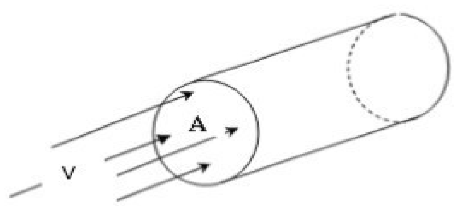


Figure: 3.12 Air moving with velocity V m/s towards area A m2

Wind is air in motion. An air mass flowing through an area A(m2) with a Velocity V(m/s) represents mass flow rate,
= Kinetic energy per second or the power possessed by moving air is, therefore, P= 1 22 Substituting for mass
flow rate in the equation for power in the wind, $Pwwww$= 1 23 As shown in the equation above, the power of the wind is proportional to the cube of the wind speed. This means that if the wind speed is doubled the power of the wind will become eightfold. The most accurate estimate for wind power density is given by following equation.

P=1 2 1 ($j3j$) wj=1 Where n is the number of wind speed reading and $j$and j are the jth reading of the air density and wind speed.

As shown in the equation output power is related to the area intercepting the wind, i.e. area swept by the wind turbine rotor. For horizontal axis turbine, the rotor swept area is, = 42 Where, D is the rotor diameter in meters. Relatively small increases in blade length or in rotor diameter produce a correspondingly bigger increase in the swept area, and therefore in power. The wind turbine with the larger rotor will generate more electricity than a turbine with a smaller rotor.

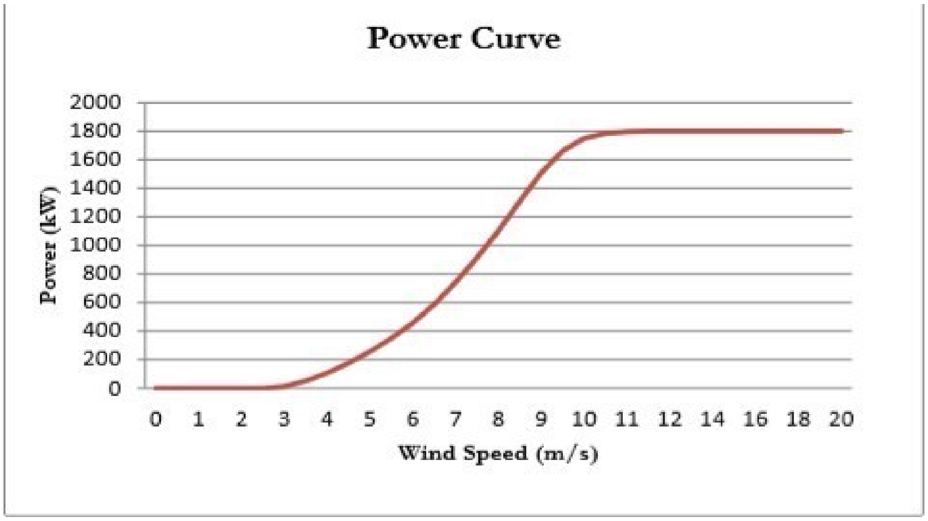


Figure: 3.13 Powers and Wind Speed Curve

Turbulence is generated by terrain features which is referred to as ambient turbulence intensity as well as by neighboring wind turbines, which is referred to as induced turbulence. Source of ambient turbulence are for example forests, hills, cliffs or thermal effects. Thus ambient turbulence can be reduced by avoiding critical terrain features. But the wake induced turbulence has far more impact than ambient turbulence intensity. Decreasing the spacing increases the turbulence induced by the wakes of neighboring wind turbines. As a general rule the distance between wind turbines in prevailing wind direction should be a minimum of the equivalent of five rotor diameters. The spacing inside a row perpendicular to the main wind direction should be minimum of three rotor diameters.

3.16 Wind Speed Distribution

Wind velocity value is the most critical data needed to appraise the power potential of a site due to its cubic relation with the power. The wind is never constant at any site. It is influenced by weather patterns, the local land terrain, and its height above the ground surface. Wind speed varies within the minute, hour, day, season, and even by year. Since wind velocity varies it is necessary to capture this variation in the model used to predict energy production. This is usually done using probability functions to describe wind velocity over a period of time. The Weibull probability density function (PDF) is given by equation.

3.17 Energy Storage System

The two main types of batteries used in hybrid systems are nickel- cadmium and lead-acid. Nickel-cadmium batteries are restricted in use for few systems due to higher cost, lower energy efficiency and limited upperoperating temperature. Lead-acid batteries is still the most common type for the hybrid systems (Mahmoud 2009). Lead–acid batteries are usually used for energy storage in hybrid systems to store surplus energy, to regulate system voltage and to supply load in case of insufficient solar radiation and/or wind. Only 2 or 3 days of autonomy is required for batteries in wind–PV hybrid systems, while 5 to 6 days of autonomy are necessary in separate PV or wind systems (Deshmukh and Deshmukh, 2008). Other storage means can be used but lead–acid batteries are a low- cost, maintenance-free and highly efficient technology. A lead acid battery in its basic construction is made of more than one electrochemical cells interconnected in such a way to provide the required voltage and current. Lead acid battery is constructed of two electrodes , the positive one consists of lead dioxide and the negative consists of pure lead (Pb). The empty space between the two electrodes is filled with diluted sulphuric acid. The voltage of the battery depends on cell temperature and the density of the acid solution, also its density changes with temperature and charge state. A battery with a 12V nominal voltage is constructed of 6*2V lead acid cells.

Chapter 4 Result and Discussion

4.1 Future Scope

As the awareness of non-renewable sources and pollution causes by them, the clean energy production with renewable sources is widely preferred and day by day implementation of such sources going on, so, research and resources are also increasing for such plants and projects. As the first time installation cost is higher due to design and manufacturing perspective. The system can be monitories using graphical user interference on computer.

4.2 Governmental policy on renewable energy and wind energy

Becoming more and more aware of the necessity of renewable energy to diminish the amount of greenhouse gasses, Bangladesh has set certain renewable energy goals. These renewable energy targets can be realized using biomass, solar and wind energy. Hydropower does not have much potential because no large height differences are present in the country. Because the available land should be mainly utilized for food production, large scale production of biomass is not possible. Bangladesh claims to have a substantial technical potential for renewable energy generation. GoB states in its Investment Plan for Scaling up Renewable Energy Program (SREP) that Bangladesh could realize over 6,000 GWh of generation from renewable technologies annually, of which a 1250 GWh can be generated from wind resources (SREDA, 2015). Nonetheless, at the moment renewable energy remains a small portion of Bangladesh's generation portfolio. Installed renewable energy generation capacity is currently 437 MW, with the 230 MW Kaptai Hydro power plant being the only grid-connected renewable resource. The remaining MWs include off-grid installations and rooftop solar providing site-specific service. GoB has set renewable energy development targets for several technologies for each year from 2015 to 2021, the "RE Development Targets". These targets require an additional 3,100 MW of renewable energy capacity to be installed by 2021. Most of the new capacity should be provided by solar (1,676 MW, or 54 percent) and wind (1,370 MW, or 44 percent). There are also targets for biomass (47 MW), biogas (7 MW) and hydroelectricity (4 MW). Figure 2.6 shows the RE development targets for each technology from 2015 to 2021.

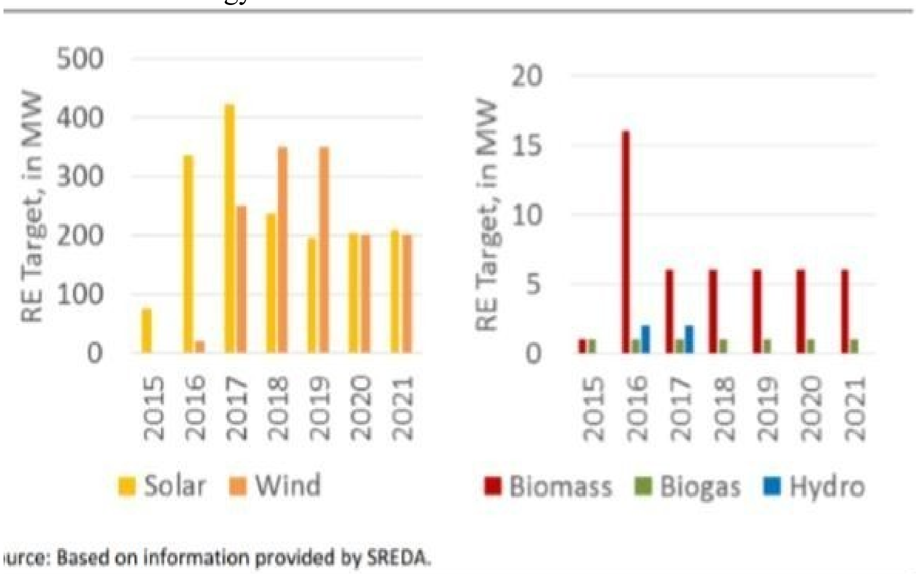


Figure: 3.14 RE Development Targets per source (edited by SREDA)

Investments in renewable energy sources are regarded with increasing interest as an effective means toward energy independence and stimulate economic growth. Numerous policies, therefore, are implemented to promote renewable sources. To shed light on this association, this paper discusses the relationship between renewable energy policies and renewable investment using a case study approach. In this paper I examine the decision-making policy process underlying RE investments. The aim of this paper is to emphasize the selections for renewable energy investment, to shed new light on RE investment decisions, and how they are influenced by renewable energy policies. This paper proposes a conceptual framework and qualitative analysis to understand the structural factors affecting the investors' decisions as well as the linkage between renewable energy policies and investment in the case study countries of United Kingdom, Turkey and Nigeria. The results suggest that renewable policies increases growth in the RE investment in the sector.

4.3 Comparison between Electricity Produce by the Wind-Solar PV Hybrid Power Generation System and Other's Fuel Energy System.

Sl. No	Wind-Solar PV Hybrid Power Generation System	Other's Fuel Energy System.
1.	It can be used again and again throughout its life.	It cannot be used again and again but one day it will be exhausted.
2.	These are the energy resources which cannot be exhausted.	They are the energy resources which can be exhausted one day.
3.	It has no carbon emission and hence environment friendly.	It has high carbon emission and hence not environment friendly.
4.	It is present in unlimited quantity.	It is present in limited quantity and vanishes one day
5.	Cost is low.	Cost is high.
6.	Renewable energy resources are pollution free.	The non-renewable energy resources are not pollution free.
7.	Life of resources is infinite.	Life of resources is finite and vanishes one day.
8.	It has high maintenance cost.	It has low maintenance cost as compared with the renewable energy resources.
9.	Large land area is required for the installation of its power plant.	Less land area is required for its power plant installation.

4.4 Pollution from Power Plants

In 2009, EPA determined that greenhouse gas pollution threatens Americans' health and welfare by leading to long lasting changes in our climate that can have a range of negative effects on human health and the environment. Carbon dioxide (CO_2) is the primary greenhouse gas pollutant, accounting for nearly three-quarters of global greenhouse gas emissions and 84% of U.S. greenhouse gas emissions.

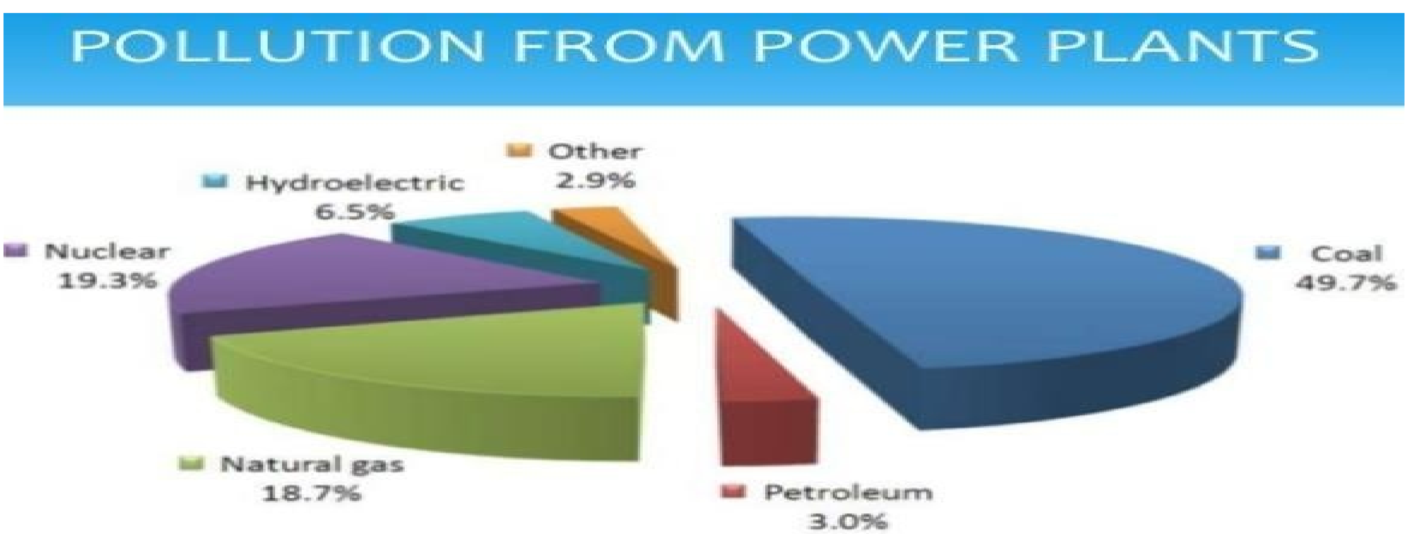


Figure: 3.15 Pollution from Power Plants

4.5 Renewable Energy Sources in Bangladesh

The prospect of renewable energy in Bangladesh is very promising, especially in the case of solar energy. However, for the near future, renewable energy will remain annexed to the current energy genesis by non-renewable conventional means. Still, renewable energy will play an important role reaching consumers outside the national grid or in places where grid connection is delayed. Major sources of renewable energy in Bangladesh are as follows:

4.6 Solar

Bangladesh is a south Asian country located in between latitudes 20°34' and 26°39' north and longitudes 80°00' and 90°41' east. Therefore, it is an ideal location for solar energy utilization. Also, as it is a subtropical country, 70% of the year sunlight is plentiful [6]. This makes the use of solar panels very effective in Bangladesh. Daily solar radiation is 4-6.5 kWh/m² and maximum radiation is generally received in the months of March-April and minimum in December-January. Hence, solar energy can be a viable solution for the power crisis in Bangladesh. Also solar energy offers some key qualities like having no waste and emission, resulting no adverse effects on the environment and ideally suited for distributed resource applications. The government has recently taken many steps to address this fact. Concurrently, some Non-Government Organization (NGO) is working to provide solar panels to consumers and the price of these panels, at present, is very affordable

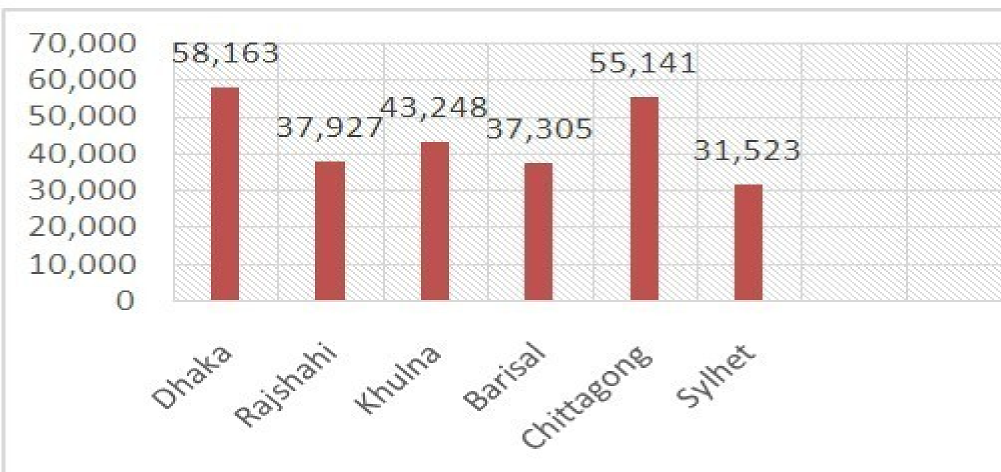


Figure: 3.16 Future Prospect of Solar Energy in Bangladesh

4.7 Wind Energy Potential of Bangladesh

Government has recognized the importance of renewable energy in our energy planning programmed and a draft Renewable Energy Policy is on the verge of being approved. In the context of Bangladesh, renewable energy consists mainly of biomass, solar energy and wind power. Hydropower potential appears very limited. Studies could be made for micro hydropower which could meet some of the local needs of electricity. This would, however, be seasonal and other forms of power generation may be required during some months of the year. There is little chance of geothermal power and further R&D would be needed to exploit wave/tidal power.

Wind energy has the potential to provide mechanical energy or electricity without generating pollutants. Historically it was used in many countries, especially, the Netherlands, as a source of mechanical energy, e.g. grinding corn or pumping water. In Bangladesh, as in many other countries, wind energy has also been used to provide some motive force to boats with sails of various designs. Unfortunately, not much research has been conducted in these areas, although renewed interest has recently been generated in utilizing the energy of wind for wind pumps and sailing boats.

4.8 Wind resources

With its sub-tropical climate, with monsoon and typhoon seasons, Bangladesh is confronted with large amounts of rainfall and periodically high wind speeds (gusts) during typhoon season. The mean annual wind speeds in Bangladesh are not well documented and few data is available. The readily available data shows that low wind speeds predominate on the Bangladeshi lands. Next to onshore wind speeds, no (extensive) data is readily available concerning (far) offshore wind speeds. The 'Solar and Wind Energy Resources Assessment' initiative also calculated the annual wind speeds in Bangladesh, this at a height of 50 meter. The data is shown in figure 3.1. The maximum annual onshore wind speeds at 50 meters in Bangladesh do not outreach 5 meters per second, and 6 meter per second for offshore wind. These can be considered as low wind resources. During the typhoon season however, there can be wind gusts with speeds well over 35 meters per second (>126 km/h). The international program Enhancing Capacity for Low- Emission Development Strategy (ECLEDS) is part of the USAID LEAD program, which supports and complements the US Government's Enhancing Capacity for Low Emission Development Strategies (EC-LEDS) initiative. EC-LEDS supports developing countries' efforts to pursue long-term, transformative development and accelerate sustainable, climate-resilient economic growth while slowing the growth of greenhouse gas emissions. Through this initiative, a current operational wind mapping project is funded. This project consists of 9 sites where a two year wind speed metering programme is in progress at heights between 20 and 200 meters (with a metmast at 20, 40, 60 and 80 metres and two SODAR's up to 200 meters). See appendix F for a short description of the program. The preliminary results of the measurement campaign are still under embargo with the Ministry of Power. Final results of the measurement campaign are expected to become public in 2018. In appendix D a rough map of the wind resources of Bangladesh is included to give an impression of the wind climate. Also Vestas, a Danish wind turbine manufacturer, has been performing wind monitoring and site assessments in Bangladesh; these results are not made public.

4.9 Wind Power

Wind power is the conversion of wind energy by wind turbines into a useful form, such as electrical or mechanical energy. The power is directly proportional to the velocity of the wind. The lengthy period wind flux, particularly in the islands and southern maritime facial of Bangladesh, announce that the average wind speed remains between 3 and 4.5 m/s in the months of March to September and 1.7 to 2.3 m/s for the residual period of the year [2]. So, in islands and coastal areas the appeal of wind mills for pumping and electrification is very high. Bangladesh Power Development Board (BPDB) has completed a 1000 kW capacity wind battery hybrid power project in Kutubdia islands [10]. Under this project, a total of 50 units of 20 kW capacity stand-alone type wind turbines are being installed. The total power generated by all the wind turbines is stored in a battery bank. Wind Battery Hybrid Power Plant (WBHPP) was officially started on March 30th, 2008. The other project of BPDB has completed a 0.90 MW capacity grid connected to wind energy at Muhuri Dam area in Feni district in 2004 [11]. The BPDB has allotted that wind energy can contribute up to 10% of the energy generated. One major benefit of wind turbines is

that they do not need any fuel for electricity generation. Table 4 below shows the feasibility of wind condition for generation of electricity at different places in Bangladesh and illuminates that maximum annual average wind speed is 2.42 m/s in Cox's Bazaar and minimum 2.08m/s in Hatia Island .

Feasibility of Wind Condition for Generation of Electricity at Different Places in Bangladesh.

Site	Reference Height (m)	Annual-Average Wind Speed (m/s)
Cox's Bazaar	10	2.42
Sandip Island	5	2.16
Teknaf	5	2.16
Patenga Airport	5	2.45
Comilla Airport	6	2.21
Khepupara	10	2.36
Kutubdia Island	6	2.09
Bhola Island	7	2.44
Hatia Island	6	2.08

$$P = (1/2) \times \rho \times A \times V^3 \text{ (in watts)}$$

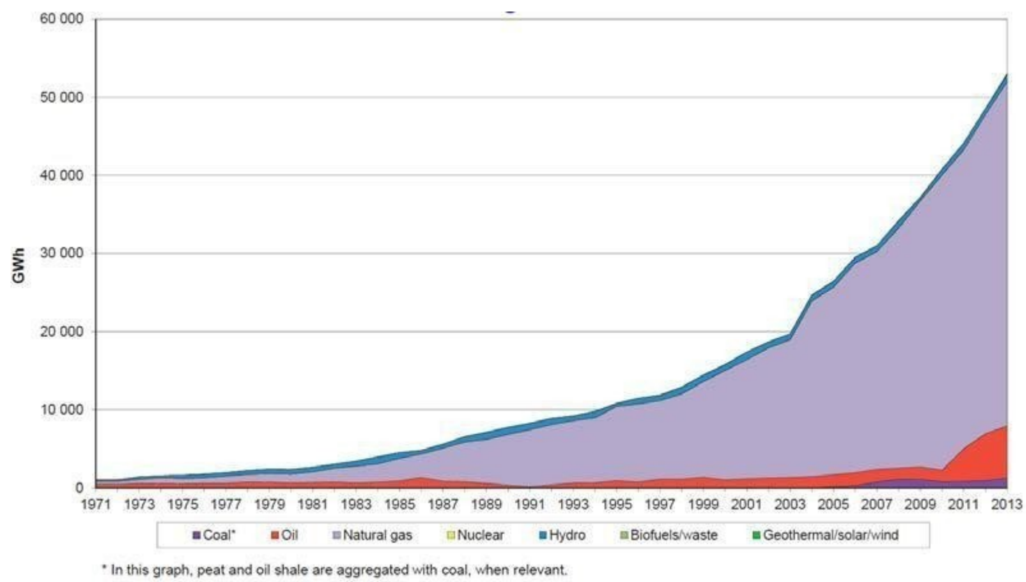
Where,
A = Area perpendicular to the direction of wind flow (in m^2)
V = Wind velocity (ms^{-1})
P = Power generation (Watts)

Table 2.1 Peak demand and peak generation 2008 – 2014[1]

	2008	2009	2010	2011	2012	2013	2014
Peak demand (MW)	5.569	6.066	6.454	6.765	7.518	9.268	10.283
Peak generation (MW)	4.036	4.296	4.698	5.174	6.350	7.356	7.817

The primary electricity generation increased rapidly as can be seen in figure 2.1, with natural gas and coal consumption growing at the fastest rates. The amount of natural gas is not enough to support the present energy demand. Moreover, this demand is constantly increasing. To meet actual demand, the Government of Bangladesh (GoB) has established quick rental projects which are mainly dependent on diesel and furnace oil. Besides these fossil resources, there is a small amount of hydroelectric power source in Kaptai (see figure 2.1).

Figure 2.1 Energy generation by source in Bangladesh in 2013 (source: EIA).



Annual wind speeds in Bangladesh (source: NREL, 2007)

Available space for wind farms

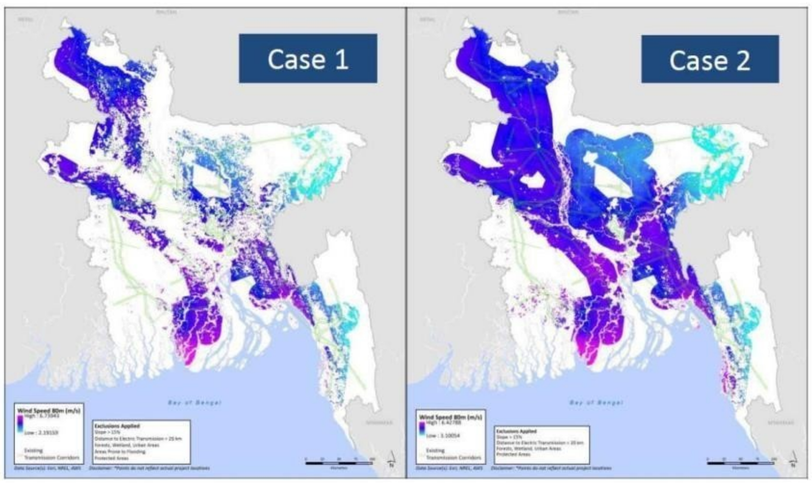
Onshore

Bangladesh is a densely populated country and being situated in the Bengal Delta, which makes large areas not usable for most activities, results in land being a scarce commodity. Figure 3.2 shows the land use of Bangladesh. As can be seen (light blue in the map), the vast majority of the country is used for agricultural purposes (maintained by irrigation processes).

Bangladesh consists mainly of flat lands. Three-quarters of the land has no elevation higher than 30 meters. The north and southeast are more elevated, in which the division of Chittagong is the most elevated land of the country (figure 3.3).

In 2015 an assessment of electricity generating renewable energy technologies was carried out with regards to the Investment Plan for the World Bank 'Scaling up Renewable Energy Program' (SREP). Several potential viable sites were identified and are shown in figure 3.4 Wind data was derived from AWS Truepower Wind Navigator (2015). For a site to be potentially viable it is required to be located within 20 km of a transmission line (see also paragraph 2.2.2). Land not suitable for wind farm installation was excluded from the assessment such as steepness of the land and flooding. Flooding is a concern for wind farms because softening of the soil could compromise the foundation of the turbines. Two cases were developed by combining wind speed data with GIS flood data, showing the resource potential when flood prone land is excluded (Case 1) and when it is included (Case 2).

Figure 3.4 Result of assessment within SREP (Case 1 excl. flood prone land, Case 2 is included)



The resource data is an extrapolation of existing data. Although based on actual measurements, it is not an accurate reproduction of the actual yearly average wind resources. Based on this assessment, and a capacity factor between 20/25% and 25/30%, the following results were presented in the SREP Investment Plan (table 3.1).

Table 3.1 Result of assessment within SREP (Case 1 excl. flood prone land, Case 2 is included)

	Case One		Case Two	
	20-25% Capacity Factor	25-30% Capacity Factor	20-25% Capacity Factor	25-30% Capacity Factor
Buildable MW	624	13	996	37

Division	Population (Millions)	Pop. Density (per km^2)	Urban Pop. %	Rural Pop. %
Barisal	8.325	630	16.4%	83.6%
Chittagong	28.423	838	24.3%	75.7%
Dhaka	47.424	1,521	32.9%	67.1%
Khulna	15.687	704	18.0%	82.0%
Rajshahi	18.484	1,018	17.9%	82.1%
Rangpur	15.787	975	13.3%	86.6%
Sylhet	9.910	784	14.8%	85.2%
Total	**144.043**	**976**	**23.3%**	**76.7%**

Source: 2011 Census, Bangladesh Bureau of Statistics.

Normal Wind Speed (m/s)

Stations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Dhaka	1.23	1.60	2.59	4.21	3.80	3.70	3.64	3.21	2.24	1.28	0.93	0.92	2.45
Mymensingh	1.07	1.45	2.18	3.21	3.21	3.21	3.01	2.68	2.10	1.32	0.87	0.78	2.12
Tangail	1.23	1.44	2.08	3.17	3.23	3.29	3.19	2.65	1.12	1.26	0.97	0.90	2.13
Faridpur	1.26	1.43	2.42	3.92	4.06	3.76	3.62	3.31	2.66	1.53	1.09	1.12	2.53
Madaripur	0.84	0.94	1.53	2.40	2.22	2.03	2.21	2.09	1.38	0.83	0.59	0.60	1.47
Chittagong	2.54	3.27	5.03	7.54	7.44	8.77	8.87	7.92	5.56	3.06	2.14	2.11	5.37
Sandwip	1.27	1.78	3.10	4.19	4.20	4.91	4.90	4.51	2.87	1.75	1.09	1.10	2.98
Sitakunda	1.12	1.57	2.56	3.21	3.21	3.70	3.54	3.19	2.19	1.21	0.86	0.83	2.26
Rangamati	1.26	1.51	2.31	2.90	2.60	2.54	2.54	2.12	1.62	1.26	1.10	1.09	1.90
Comilla	1.16	1.58	2.81	4.30	4.36	4.64	4.73	4.10	2.69	1.44	0.89	0.88	2.82
Chandpur	0.85	0.96	1.92	2.80	2.22	2.21	2.12	1.87	1.36	0.92	0.72	0.67	1.56
M_Court	0.71	1.08	1.81	2.91	2.84	3.41	3.45	3.01	1.98	1.08	0.71	0.60	1.98
Feni	0.84	1.26	1.97	2.95	2.75	3.17	3.43	3.02	2.01	1.00	0.70	0.63	1.96
Hatiya	2.33	2.53	3.57	5.14	5.02	5.81	5.64	4.67	3.38	2.06	1.63	1.65	3.63
Cox's_Bazar	3.60	3.85	4.30	4.84	5.36	6.15	6.41	5.75	4.20	3.15	2.93	3.13	4.48
Kutubdia	2.52	2.64	3.38	3.88	4.02	5.40	5.40	4.78	3.13	2.19	1.72	1.93	3.43
Teknaf	1.93	2.44	2.54	2.15	2.27	2.39	2.48	2.27	1.49	1.29	1.21	1.16	1.97
Sylhet	2.18	2.68	3.25	3.25	2.82	2.56	2.39	2.18	1.84	1.84	1.98	2.07	2.42
Srimangal	0.46	0.91	1.63	1.83	1.53	1.42	1.63	1.21	0.87	0.58	0.36	0.30	1.07
Rajshahi	1.64	1.77	2.26	3.40	3.73	3.55	3.24	2.90	2.45	1.53	1.45	1.66	2.46
Ishurdi	1.57	1.75	2.64	4.62	4.92	4.73	4.23	3.85	2.89	1.58	1.34	1.53	2.98
Bogra	1.29	1.58	2.17	3.07	3.12	2.90	2.65	2.38	1.90	1.20	0.96	1.05	2.02
Rangpur	1.25	1.59	2.50	3.40	3.01	2.93	2.77	2.60	2.14	1.63	1.46	1.25	2.22
Dinajpur	0.98	1.20	1.72	1.99	1.76	1.74	1.62	1.43	1.18	0.81	0.66	0.69	1.32
Sayedpur	2.67	3.14	4.60	4.76	4.00	3.73	3.56	3.05	2.74	2.12	2.04	2.24	3.22
Khulna	1.34	1.61	2.48	3.72	3.74	3.34	3.20	3.25	2.23	1.27	0.97	1.07	2.38

Mongla	1.86	2.05	2.71	3.96	4.17	3.98	3.70	3.46	2.71	1.87	1.45	1.50	2.78
Satkhira	1.54	1.81	2.50	3.75	3.72	3.16	2.83	2.56	2.05	1.51	1.40	1.47	2.36
Jessore	1.38	1.85	3.42	6.00	6.25	5.41	4.84	4.29	3.37	1.71	1.19	1.11	3.42
Chuadanga	0.82	0.95	1.57	2.47	2.44	2.31	1.99	1.71	1.55	0.94	0.62	0.66	1.50
Barisal	0.64	0.96	1.85	3.11	3.00	2.92	2.84	2.45	1.62	0.83	0.54	0.56	1.78
Patuakhali	1.61	1.77	2.72	3.93	4.02	3.69	3.59	3.23	2.42	1.51	1.24	1.16	2.56
Khepupara	1.75	2.19	3.63	5.64	5.92	5.72	5.58	4.96	3.36	1.77	1.36	1.37	3.62
Bhola	0.61	0.93	1.65	2.81	2.40	2.19	2.21	1.87	1.28	0.65	0.47	0.52	1.47

Chapter 5 Conclusion

5.1 Advantage of Hybrid System

1. Very high reliability (Combine wind power, and solar power)
2. Long term Sustainability and Long Term warranty
3. High energy output(since both are complimentary to each other)
4. Cost saving (only one time investment)
5. Low maintenance cost (There is nothing to replace)
6. No pollution, Clean and pure energy
7. Provides un-interrupted power supply to the equipment
8. The System gives quality power out-put DC to charge directly the storage battery or provide AC.
9. The system can be designed for both off-grid and on grid application.

5.2Disadvantae

1. Large number of harmonics is produced
2. Initial investment is more
3. Large space is required for larger generations
4. Wind energy system are noisy in operation, a large unit can be heard many kilometers away.
5. Efficiency is less than conventional power plants.
6. The arrangement becomes complicated due to hybrid structure.
7. Large space is required for larger generations.

5.3 Conclusions

In this article, we presented hybrid renewable energy systems (HRES) on the one hand, and a system analysis and improvement method of a PV/Wind hybrid energy system, on the other hand. In fact, hybrid power systems combine two or more energy conversion devices, or two or more fuels for the same device, that when integrated, overcome limitations inherent in either. They can offer solutions and value to customers that individual technologies cannot match. This method was permit to identify the different functions and components of the HRES as. It has given details on wind and solar energy separately then coupling them to form a hybrid power system. The hybrid power system was discussed as a whole. Including the auxiliary components such as charge controllers and converters. This give an Opportunity to therefore look at the design of the hybrid power system.

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