Hybrid Energy System

Ishani Engineer
Electrical Engineering
Atharva College of Engineering,
Mumbai, Maharashtra.

Vijetha Jogu
Electrical Engineer
Atharva College of Engineering,
Mumbai, Maharashtra.

Shruti Jadhav
Electrical Engineer
Atharva College of Engineering,
Mumbai, Maharashtra.

Puja Nalawade
Electrical Engineer
Atharva College of Engineering,
Mumbai, Maharashtra.

Pooja Sawant
Electrical Engineer
Atharva College of Engineering,
Mumbai, Maharashtra.

***Abstract*— In analogous to developing technology, demand for more energy makes us seek new energy sources. The most significant application field of this search is renewable energy resources. Wind and solar energy have being popular ones due to abundant, ease of availability and convertibility to the electric energy. This work covers understanding of a hybrid renewable energy system for a domestic application, which runs under a microcontroller to make use of the solar and wind power. This project is implemented in accordance with available line electricity. Batteries in the system are charged by either wind power through a small alternator or solar power through an MPPT Module. System control depends mainly on microcontroller. Power resources and loads in the system are monitored and controlled in real life.**

***Keywords*— Grid; Hybrid energy system; MPPT; Storage**

I. INTRODUCTION

Hybrid energy source is becoming popular because it is contains two or more energy sources. Due to this combination of two energy sources, it is an efficient way of generating energy. Hybrid energy systems are used in remote areas for power generation. This is widely used due to the high prices of oil. The use of hybrid energy systems can optimize the power supply especially in rural areas. However it is still considered expensive and also it is difficult to combine two or more energy sources together, but it is a onetime expense. This onetime expense can be of many uses to the people living in remote areas.

II. ENERGY DEMAND

A. Renewable 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 if they are to be used for commercial purposes then the cost of fueling them will increasingly become difficult. The photovoltaic system and Wind power have an important role to play in today's life. Figure 1 is the schematic pie chart of Solar-Wind Hybrid system that can supply either dc or ac energy or both.

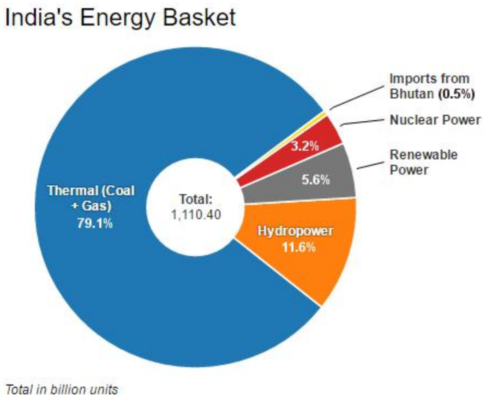

Fig 1. India's energy generation diagram.

III. SOLAR AND WIND POWER GENERATION

A. Solar Energy

Solar panels is also known as modules and it contains photovoltaic cells made of silicon that transforms incoming sunlight into electricity. ("Photovoltaic" is basically electricity from light — photo = light, voltaic = electricity.)

Solar photovoltaic cells are made of a positive and a negative silicon film placed under a thin slice of glass. As the photons of the sunlight strikes on silicon cells, the electrons ejects from the film. The electrons which are negatively charged are attracted to one side of the silicon cell, this creates an electric voltage that can be collected and channeled. The solar photovoltaic array is formed by collecting the current by wiring different solar panels. Fused array combiner is an electrical box in which multiple strings of solar photovoltaic array cables terminate; it is depending on the size of installation. Contained within the combiner box are fuses which are designed to protect the individual module cables, as well as the connections which delivers power to the inverter. The electricity produced at this stage is DC and must be converted to AC using inverter which is suitable for use in home or business.

Solar system could be categorized into two types:

- Line-independent systems: These are established in absence of line electricity to provide electricity The DC current is obtained in this system which is stored in accumulator
- Line-dependent systems: These systems do not required any DC-Batteries, since the energy is served to the demand with the help of an inverter. Line electricity is being in use in case of insufficient sun beam.

B. Wind Energy

The energy of wind is converted into useful form (usually electric current) is called wind energy. Wind turbine converts the wind power into useful electric power. Electric generator used inside the turbine converts the mechanical power into the electric power. Wind turbine systems are available in ranges from 50W to 2-3 MW. The energy produced by wind turbines depends on the velocity of wind acting on the turbine. Wind power is used to feed the energy production as well as consumption demand, and transmission lines in the rural areas. Wind turbines can be classified depending on the physical features (dimensions, axes, number of blade), generated power and so on. Power production capacity can be classified in four subclasses.

• Small Power Systems
• Moderate Power Systems
• Big Power Systems
• Megawatt Turbines

IV. HYBRID ENERGY

Hybrid systems uses more than one energy resources that can be renewable or non-renewable. Integration of systems (wind and solar) has more impact in terms of electric power production. Such systems are known as “hybrid systems”. Hybrid solar and wind applications are implemented in the field, where entire year energy is to be consumed without any chance for an obstacle. It is possible to have any combination of energy sources to supply the energy in the hybrid systems, such as oil, solar and wind or others. This project is somewhat similar with solar power panel and wind turbine power of course; it is only an add-on in the system.

Solar panels and small wind turbines depend on environmental conditions. Therefore, neither solar nor wind power is used alone. A number of renewable energy experts say to have a satisfactory hybrid energy resource if both wind and solar power are integrated within a unique system. In the summer time, when sun beams are strong enough, wind velocity is relatively less. In the winter time, when sunny days are relatively shorter, wind velocity is high. Efficiency of these renewable systems show also differences throughout the year. In other words, it is needed to compensate these two systems with each other to get the continuous of the energy production in the system.

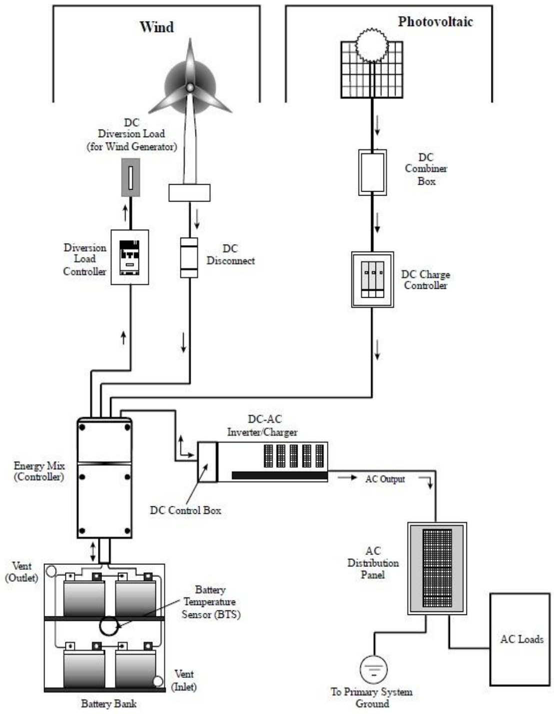

Fig. 2 Hybrid system block diagram

In the realized system, a part of the required energy for an ordinary home has been obtained from electricity that is received from the wind and solar power. Praticle setup for the domestic hybrid system consists of a low power wind turbine and two PV panel. Depending on the natural conditions, required energy for the system can be distributed either separately from the wind or solar systems or using these two resources at the same time. Control unit is the deciding factor, which source to use for charging the battery with respect to condition of the source energy.

Wind turbine first converts the kinetic energy of wind to mechanical energy and then converts it to the electricity. The wind turbine in the system consists of tower, alternator, speed converters (gear box), and propeller. And a demonstration of the constructed hybrid system is show in Figure

Fig. 3.Hybrid system

The kinetic energy generated from the wind is converted to the mechanical energy in the rotor. The rotor shaft speed is, 1/18, is increased in the reduction gear and then passed on to alternator. The electricity that comes from the alternator can be transmitted to DC receivers as well as it can be stored in the batteries. The solar panels in the system convert the day light in to electricity. The solar panels can generate major amount of electricity even in the abnormal weather conditions. MPPT regulates the energy coming from these panels and ensures a continuous high power generation.

V. INTEGRATION SCHEMES

A. *Stand-alone hybrid system*

- Series hybrid system*:* There are two forms centralized dc-bus and centralized ac-bus. In centralized dc bus, all the energy sources, storage devices, and loads are connected to a dc-bus through suitable electronic devices. The dc-bus eliminates the need for frequency and voltage controls of individual sources connected to the bus and the power supplied to the load is not interrupted. Harmonics due to power electronic can be reduced as DC loads are connected directly. DC-bus configuration has low efficiency limitation because in case of both source and load are AC. Also, there will be power loss if inverter gets fail and if inverter is not rated for the peak load requirements. In centralized ac-bus, through appropriate electronic devices, all the energy sources, storage devices, and loads are connected to an ac-bus. It facilitates the growth to manage the increasing energy needs. It offers major restriction in the synchronization of the inverters and ac sources to maintain the voltage and frequency of the system. The harmonics are introduced due to use of inverter.
- Parallel hybrid system: In this system the ac sources and loads are directly connected to ac-bus and the dc sources and loads are directly connected to dc-bus. Bidirectional converter connects both the buses to permit the power flow between them. The inverter rating is less than that of series system and the efficiency is higher. The power supplying capacity of the parallel configuration is much more for the same inverter rating as that used in series configuration. Thus, such configuration arrangement has advantages as it increases the system reliability and ensures the uninterruptable supply.
- Switched hybrid system*:* In this configuration the ac sources, such as wind generator, can directly be connected to the load leading to higher efficiency and synchronization in not needed. It has several limitations that only one of the sources is connected to the load at a given instance. This is popular configuration. Furthermore, during switching between the sources, the power is interrupted.

B. *Grid connected systems*

The selection of the layout for particular location depends upon geographical, economical, and technical factors.

- Centralized dc-bus architecture: In this ac energy sources, such as wind generator, firstly the power deliver to rectifiers to be converted into dc before being delivered to the main dc bus bar. An inverter is used to feed the ac grid from this dc bus.
- Centralized ac-bus architecture: The sources and the battery through appropriate power electronic devices are installed in one place and are connected to a main ac bus bar, then connected to the grid. This system is centralized means the power delivered by all the energy conversion systems and the battery is fed to the grid through a single point.
- Distributed ac-bus architecture: The power sources do not need to be installed close to each other, and they do not need to be connected to one main bus. The sources are distributed in different locations and then connected to the grid separately. The power produced by each source is conditioned separately to be identical with the form required by the grid.

VI. MAXIMUM POWER POINT TRACKING

The Maximum Power Point Tracking (MPPT) is a technique which regulates the power coming from the solar panel to get high efficiency output to charge the battery at specific voltage and to avoid loss of energy. However, there are two major disadvantages for the use of PV systems, low energy conversion efficiency and high initial cost. To improve the energy efficiency, it is important that PV system work at its maximum power point. A maximum power point tracker is used for obtaining the maximum power from the solar PV module and conversion to the load. A DC-DC converter (step up or step down) is used for conversion maximum power to the load. A DC-DC converter acts as an interface between the load and the module. By varying the ratio of duty cycle the voltage and current is stepped up or down as per the voltage required at the output and the panel is made to work at high efficiency.

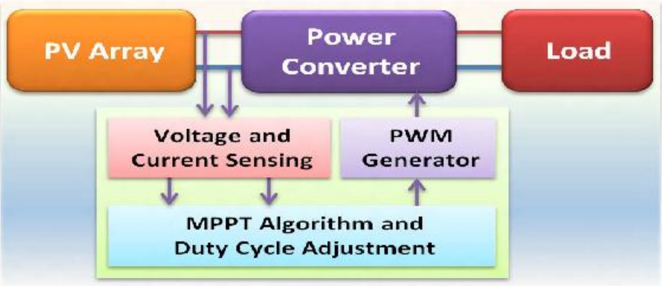

Fig. 4. MPPT block diagram

A. *Perturb and Observe (P&O)*

The most popularly used MPPT algorithm is P&O method. This algorithm uses simple feedback mechanism. In this method, the module voltage is periodically given a perturbation and the corresponding output power is compared with the previous perturbing cycle. If the power increases due to the perturbation then it is continued in the same direction. After the peak power is reached (MPP), in the next feedback instant the power decreases hence after this the perturbation reverses. When the stable condition arrives the algorithm oscillates around the maximum power point(MPP). A PI controller then transfers the operating point of the module to that particular voltage level. This voltage is used in Pulse width modulator so as to generate a triggering signal for DC to DC converter. And the required voltage level is achieved to charge the battery. It is observed that there are some power losses due to this perturbation. It fails to track the maximum power under fast changing atmospheric conditions.

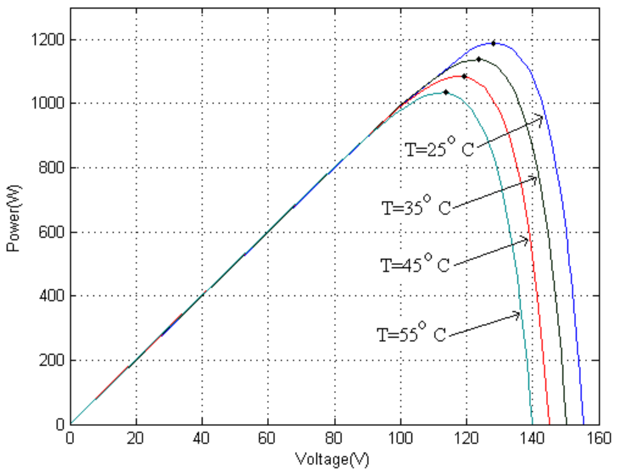

Fig. 5. Power-voltage graph (PV cell)

B. *Incremental Conductance (IC)*

The algorithm oscillates around peak power point of the P & O method to track the peak power under fast varying atmospheric condition. This can be overcome by IC method. The Incremental Conductance can determine whether the MPPT has reached the MPP and it stops perturbing the operating point. If this condition is not met, the direction in which the MPPT operating point must be perturbed and this can be calculated using the relation dI/dV and I/V. This relationship is derived from dP/dV which is negative when the Maximum power point tracking is to the right side curve of the MPP and positive when it is to the left side curve of the MPP. dP/dV is zero when it has reached MPP. This algorithm has advantages over P & O method in that it can determine when the MPPT has reached the MPP. Also, IC method can track rapidly increasing and decreasing irradiance conditions with higher precision than P & O. The disadvantage of this algorithm is the increased complexity.

C. *Constant Voltage Method*

The Constant Voltage method (CV) uses the fact that the MPP voltage at different irradiance is approximately equal, as shown in

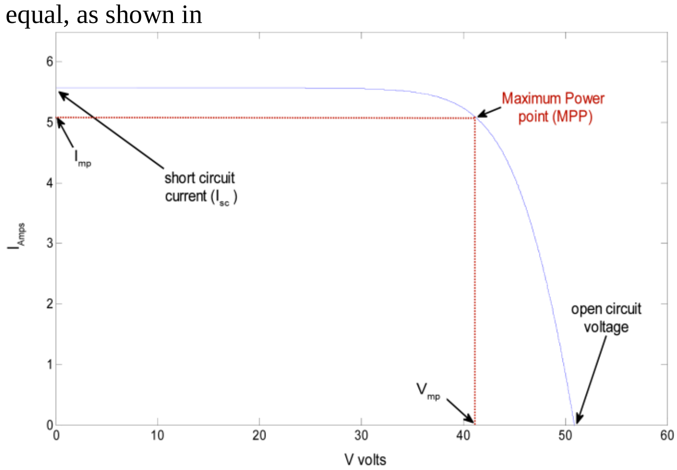

Fig. 6. Voltage-current graph (PV cell)

VOC represents the open circuit voltage of the PV panel. It depends on the property of the solar cells. A commonly used VOC/VMPP value is 76%. This relationship can be described by equation below:

VMPP = k * VOC

Where k ≈0.76

The solar panels are disconnected from the converter circuit for a short duration of time for VOC measurement. The operating voltage of the MPP is set to 76% of the measured VOC.

The major advantage of this method is that the Maximum power point (MPP) can be located very quickly. However this method has a disadvantage that it suffers from low accuracy, because the VOC is also affected by the temperature of the solar cells which may change the VOC/VMPP ratio. Any small deviation of the VOC after the sampling can cause large difference in tracking the MPP during that sampling. Power is usually lost during the short sampling time, further reducing the efficiency of constant voltage method.

MPPT working

B is a variable used to find the intermediate value between current and voltage. B is calculated by using the following equation.

ln (Ipv /Vpv) – C. Vpv = ln (I0.C) = B

Where Ipv represents panel output current, Vpv represents panel output voltage. C represents conductance, is calculated by using

C=q /(η K T Ns)

Where q represents the electron charge, η represents the quality factor of the junction panel, K represents the Boltzmann constant, T represents the temperature, and Ns represent number of cells in series.

It may be noted that B is independent of exposure to radiation but depends on temperature. The initial step of the algorithm is reading the panel output voltage (Vpv) and panel current (Ipv) measured from Photovoltaic panel. After getting the value Vpv and Ipv the B value is calculated. Check if B value is in steady state or not. If B is in the steady state, then B is checked whether it is within range of steady state or not. If B in that range then it is switched to other methods. After that same process is repeated again from the initial state. If the B is not in steady state, it starts processing from the initial steps. If the Ba is not in the steady state range and then error value is calculated. Bg, the value of B corresponding to the most probable array temperature is used as the guiding value.

Error = Bg – Ba

The steady state value is calculated by a fixed temperature, the difference in the magnitude value of B at maximum power point lies smaller, from that B min and B max ranges are fixed. Smaller changes irradiation level made changes in wide range. B Max is taken from maximum irradiation in maximum temperature. B Min is taken in minimum irradiation and in minimum temperature. Both values B Min and B Max calculated at maximum power point. Error values are calculated from the difference between Bg and Ba. From that new duty is calculated, by summing the old duty cycle with the product of error and Boltzmann constant.

$$d_{new} = d_{old} + (\text{Error} \times \text{K})$$

d_{old} is the previous duty cycle, d_{new} = new duty cycle and K is a constant corresponding to the B plot. After that new duty cycle is checked whether the new duty cycle is lies between the dMin and dMax. From that duty cycle is calculated for DC-DC converter.

VII . ENERGY STORAGE

Energy storage is an important factor in hybrid system as it involves generation and usage whenever required . thus it an important factor. There are two main functions of it. First it compensates the mismatch of load and source that is the power generated and the power required by the load. These can be of further two types.

A . *Convertible*

It is one of the forms of energy storage, it includes compressed air energy system, fuel cells, hydrogen, pumped hydrogen system, superconducting magnetic energy system, super capacitors, and it basically includes all the non-renewable sources of energy as their storage system. Out of all these battery is the most efficient, so battery is used as compared to all the other sources.

- Battery- they are the most preferred convertible form of source in hybrids system. The most common type of storage battery for hybrid energy applications is the lead acid battery. Nickel Cadmium has also been used occasionally for this application. Following are the categories on which a battery works hey include: voltage, energy storage ability, charging and discharging rates, efficiency, and battery life cycle. Batteries are usually DC in nature. Cells are arranged in series, with each cell nominally two volts, given a capacity of two volts. In market they are available of 2,6,12, and 24 volts. But the actual terminal voltage will depend on three factors: state of charging, whether the battery is being charged or discharged, and the rate at which it charges and discharges. The energy storage is the key function of a battery, its efficiency is decided on the basis of its maximum energy storing capacity and the rate at which charges and discharges. Also the amount of energy it can hold decides the strength of a battery this in turns depends on the materials used during the construction of battery making. Apparent capacity of batteries actually differs with charge and discharge rate. Higher rates result in smaller apparent capacities. Experience has shown that the process of using batteries actually lower their storage capacity until eventually the battery is no longer useful. While considering a battery the life cycle of it and its rate of charging and discharging are given major attention.

- Others-Super conducting magnetic energy storage is the one with highest efficiency till date but it's not economically good as it has very high prize dude to the use of high cost conducting coils in its construction hydrogen and super capacitors require additional technical support for its application so they are not used in practice, Pumped hydrogen system is not feasible for small scale usage as its efficiency is low and costing is high cost involved with the system. Compressed air natural energy system is relatively cheap but it requires underground air compressed system which is practically difficult to obtain so even they are not used. Flywheels are efficient and have low cost, but the disadvantage factor is they have a high discharging rate.

B. *End Use Storage*

End-use, storage system is used when the energy is available it is another form of energy then convertible. The duct is then stored and made available when it is needed. Load management schemes often take into account some end-use storage. It includes Thermal Energy, Pumped Water and Pure water.

VIII. ECONOMICS

There are several economic criteria for the system cost analysis, such as Net annual Cost, levelised Cost of Energy and life-cycle cost. The Net present Cost is defined current prizes which includes parts of the system, the cost of any component's exchange that occur within the project lifetime and the cost of maintenance. The life of PV modules is generally considered as the life of the system. The Levelised cost of energy is the ratio of the total annualized cost of the system to the annual electricity delivered by the system. The cost of energy of a hybrid system is determined by two factors: The cost of the system and the amount of useful energy that is produced. Some other factors include the energy content, the cost of conventional energy, lifetime of the system, maintenance costs and financial costs initial cost of all the system components, market prize of other part of system replacement of damaged components of the system, also the life cycle of the system. The life of PV modules is generally considered as the life of the system.

The cost of a hybrid energy system is first of all affected by the cost of the each and every component that makes up the system. Installation of the components and any changes we bring in to the existing components will add to the cost. Generally, the renewable energy generators themselves are the most expensive items. The energy that can be obtained from a renewable source depends on its generator, its productivity at different levels of the resource, and the distribution of the applications of those levels. For example, a wind turbine will produce energy depending on the wind speed. If the average wind speed each hour is known, this information can be combined with the data received from the turbine power curve to predict the total energy that the turbine could produce. Similar curves describe the output of solar panels. These curves, combined with hourly data on the solar resource, can give an idea of the total annual energy from the panels. Economics of hybrid energy systems are generally evaluated by a technique known as life cycle costing. This method give an idea of the fact that hybrid energy systems have relatively high starting prize but long lifetimes and low operating costs. These factors, together with various financial parameters, are used to predict present value costs, which can then be compared with costs from the conventional alternatives.

IX. TRENDS

Hybrid energy systems are still an emerging technology. It is expected that technology will continue to evolve in the future, so that it will have wider applicability and lower costs. There will be more perfect designs, and it will be easier to select a system necessary to particular applications. There will be increased communication between components. This will facilitate control, and diagnosis. Finally, there will be increased use of power electronic converters. Power electronic devices are already used in many hybrid systems, and as costs go down and reliability increment, they are expected to be used more and more.

X. LIMITATION

The renewable technologies have a vast scope in terms of research and development. However there are certain obstacles in terms of their efficiency and optimal use. Following are the disadvantages or limitations of a hybrid system.

- The renewable energy sources, such as solar PV and FCs, need modern technology to harness more amount of useful power from them. The less efficiency of solar is major disadvantage in encouraging its use.
- The manufacturing cost of renewable energy sources need to be reduced because the high money cost leads to an increased payback time.
- It should be ensured that there should be least amount of power loss in the power electronic devices.
- The storage technologies need to increase their life-cycle through modern technologies.
- These stand alone systems are less preferable to load fluctuations. Large variation in load might even lead to entire system collapse.

XI. CONCLUSION

The available power from the renewable energy sources such as wind, solar source is extremely dependent on environmental conditions such as wind and water velocity, radiation, and ambient temperature etc. To overcome deficiency in the solar and wind system, we integrated them and produce hybrid energy. Parallel hybrid system can be preferred due to higher efficiency and also due to more supplying capacity than the other configurations of grid system. Switched hybrid system also has more efficiency but it has several limitations. Out of the convertible and end use energy storage system convertible are the preferred ones. Out of the convertible batteries are most efficient. The major factors to be considered for batteries are its capacity, discharging rate, size and the material used.

REFERENCE

[1] Enslin, J. H. R., "Maximum Power Point Tracking: A Cost Saving Necessity In Solar Energy Systems", *16th IEEE Annual Industrial Electronics Society Conference,* Pacific Grove, USA, 1990, pp.1073-1077.

[2] L, Fagbile ."Estimation of Total Solar Radiation in Nigeria Using Metrological, Nigeria *Journal of Renewable Energy* **1**,1-10. (1990).

[3] Hunter, R., and Elliot, G. (1994). ''Wind-Diesel Systems.'' Cambridge University Press, Cambridge, United Kingdom.

[4] ArjavHarjai, AbhishekBiswajit, and MryutunjaySandhibirgha, "*Evaluation of Maximum Power Point Tracking Methods In Solar Photovoltaic Array*," Project Report, National Institute of Rourkela, Orissa, 2008.

[5] S.Balakrishna, N. A. Thansoe, G. Rajamohan, A. S. Kenneth and C. J. Ling, "The Study and Evaluation of Maximum Power Point Tracking Systems," International Conference on Energy and Environment 2006 (ICEE 2006), pp. 17-22, 2006.

[6] Md. Ibrahim, Abul Khair,Shaheer Ansari, "A Review of Hybrid Renewable Energy Systems for Electric Power Generation", ISSN: 2248-9622, Vol. Issue8, (Part - 1) August 2015, pp.42-48

[7] Burton T., Sharpe D., Jenkins N., Bossanyi E., "Wind Energy Handbook", John Wiley & Sons Ltd., England, 2001, pp. 41-170

[8] Akikur, R. K., Saidur, R., Ping, H. W., and Ullah, K. R., "Comparative Study of Stand-Alone and Hybrid Solar Energy Systems Suitable for Off-Grid Rural Electrification:A review," Renewable and Sustainable Energy Reviews, Vol. 27, pp. 738-752, 2013.

[9] Markvart T. Sizing of hybrid PV–wind energy systems. Solar Energy 1996;

[10] Bagul AD, Salameh ZM, Borowy B. Sizing of a stand-alone hybrid wind photovoltaic system using a three-event probability density approximation. Solar Energy 1996; 56(4).