Solar-Wind Hybrid Power Generation Model For Small Rural Households

Yashasvi Mishra[1], Saurabh Kumar[2]
Department of Electrical and Electronics Engineering
[1,2] Oriental University Indore, India

Abstract- *The ever increasing demand of electrical energy has already led to shortage of conventional resources. Beside the shortage the use of conventional power generation technique has adverse effects on environment leading to serious issue like global warming. The alternative for all these concerns are to shift towards green energy. The renewable energy sources like solar, wind and hydro can be harnessed efficiently to mitigate all the problems related to conventional power generation technique. The basic concept behind hybrid technique is to increase the reliability along with maximizing the renewable resource usage.*

This paper deals with solar wind hybrid generation model and simulation. The renewable energy sources like solar and wind energy are combined to increase the total power generation and hence increase the efficiency of hybrid system. The combination also provide a means to overcome intermittent nature of solar and wind renewable energy sources as one source can be used for power generation when other is not available. The output of solar cell and wind turbine using DC generator is essentially DC, which is stored in battery. The energy stored can be utilized to drive DC load as well as AC loads can also be driven by use of converter circuit.

Keywords- Solar panel; DC generator; lead acid battery; HAWT

I. INTRODUCTION

The intensive consumption of fossil combustibles is the main cause for the negative impact on our atmosphere. In fact, the fossil combustibles are the main energetic source that sustains the worldwide development. Powers are mainly delivered by fossil combustibles. Today, due to the increasing international concern on the Earth climatic changes we are assisting to an intense research on alternative energetic sources. We can discuss on two renewable sources: wind power and solar photovoltaic (PV). Both these energetic sources are clean and worldwide available. The comparative advantages of these energetic sources in relation to other renewable energies are demonstrated by the intense expansion of both wind and photovoltaic (PV) production plants, This expansion is not due to direct exploration costs but mainly motivated by its reduced impact on environment. However, these renewable resources are extremely useful in under developed countries, with small needs on electricity and low density populations, where small communities are distributed along great geographical extensions The coverage of long distances by electric distribution networks are extremely expensive and completely away from the economical budget of poor countries, especially in Africa. In these cases, of distant rural communities, the electricity generation by means of photovoltaic and wind systems are financially advantageous, relatively to transported electricity through standard networks. A sub-sized system obviously does not satisfy the demand on electric power and, on the other hand over-sized system can be completely prohibitive due to economical and financial indicators. The different types of renewable sources are specifically evaluated in the economical performance of the overall equipment. The presented methodology was applied to evaluate the design of a solar-wind hybrid system to produce electricity.

II. PROPOSED WORK

The collection of data for PV and wind turbine is carried out for a given specific area where the hybrid system is installed. The cost of available components in local market and the availability is ensured for economic consideration. The sizing of panel, wind turbine blades, pole length and the capacity of storage system is decided. Accordingly the output capacity of converter is decided on the basis of ac load requirement. The PV module with 36 cells are connected in series to meet the charging requirement of 6volt 5Ah lead acid battery, which is sufficient to meet the daily requirement for small domestic loads. The open circuit voltage at full efficiency of solar module is 21.6 volt as well as the output power is 12 watt. The sizing of wind turbine blades are done by taking reference value of 1:3 (i.e. blade is to pole) ratio. The effective length of blades in the model is 10cm and the height of pole is 30cm. The average wind speed in Indore is 3.07(m/s) at the height of 50 m from the ground and annual average radiation received is 5.63(kW/m2/day).The hybrid system output is stored in Lead acid battery so that it can be used for backup in case of power failure; selection of battery capacity is done by taking short circuit current from solar module as charging current. The hybrid system is the solution for all the environmental and power shortage concerns across the globe. The hybrid system of solar and wind resources is most feasible because it uses the renewable energy sources as input and yields very good output efficiency.

Block Diagram of Solar-Wind Hybrid Generation System

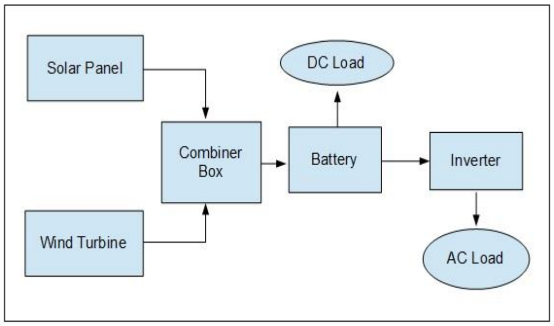


Fig.1 Block Diagram of Solar-Wind Hybrid Generation System

Solar Panel

It is a device which converts the light energy into electrical energy. When light is allowed to fall on this cell, the cell generates a voltage across its terminals. This voltage increase whit increase in the light intensity. The cell is so designed that a large area is exposed to light which enhances the voltage generation across the two terminals of the cell. Construction and working is explained below. It essentially consists of a silicon PN junction diode with a glass window on top surface layer of P material is made extremely thin so, that incident light photon's may easily reach the PN junction. When these photons collide with valence electrons they comport them sufficient energy as to leave their parent atoms. In this way free electrons and holes are generated on both sides of the junction. Due to these holes and electrons current are produces. This current is directly proportional to the illumination's (MW/cm2) and also depends on the size of the surface area being illuminated.

Wind Turbine

This prototype consists a wind turbine with three blades that converts the kinetic energy of air into mechanical (rotational) energy. The blades are made using aluminum sheet to make it lighter in weight and are mounted on rotor shaft connected to PMMC generator. The sizing of blade and the height of the pole on which the entire turbine is established is decided as per the ratio which is 1:3 for length of blade and pole.

DC Generator

In a DC generator, the armature is rotated by an external mechanical force, in this prototype by a wind turbine. This rotation induces a voltage and current flow in the armature. Thus the armature converts mechanical energy into electrical energy.

Wind Turbine Blades

The horizontal axis wind turbines (HAWTS) basically use one, two, three and multi blade rotors. Multi blade rotors have become obsolete or are used very less due to its design complexity. Two blade and three blade rotors are used widely. The only real advantage a turbine with two blades is the reduced cost and weight of a third blade. However, since a two blade wind turbine can't capture as much energy from the wind as a three blade turbine can, it has to be designed to operate at higher RPMs to produce the same amount of power. When it comes to small wind, this can hardly be seen as an advantage. They also suffer from a dynamic imbalance. For instance, when the top blade is in the wind the bottom blade is being shaded by the tower. This causes problems with yawing and puts unnecessary wear on the bearings. This makes them particularly unsuitable for high wind areas. Three blades successfully eliminate these problems. In the end three blades rule the day.

Lead-Acid Battery

The battery used in this model for storage has the output voltage of 6 V and capacity of 5 Ah. The sizing of solar panel is decided by the charging current of the battery which is calculated by dividing the capacity of battery by constant value 10 (for lead-acid battery). The storage battery or secondary battery is such battery where electrical energy can be stored as chemical energy and this chemical energy is then converted to electrical energy as when required. The conversion of electrical energy into chemical energy by applying external electrical source is known as charging of battery.

Mathematical Formulation

$$I = I_L - I_D - I_{SH} \quad \ldots..$$

Equation No. 1

Where

I = Output Current (Ampere)

I_L = Photogenerated Current (Ampere)

I_D = Diode Current (Ampere)

I_{SH} = Shunt Current (Ampere)

2. Open Circuit Voltage and Short Circuit Current Equation

$$V_{oc} \approx \frac{nkT}{q} \ln\left(\frac{I_L}{I_0} + 1\right) \quad \ldots..$$

Equation No. 2

Where

n = Diode Ideality Factor

q = Elementary Charge

k = Boltzman Constant

T = Absolute Temperature

I_0 = Reverse Saturation Current

$$I_{SH} \approx I_L$$ …..

Equation No. 3

3. Global formula to estimate the electricity generated in output of a photovoltaic system

$$E = A \times r \times H \times PR$$ …..

Equation No. 4

Where

E= Energy (kWh)

A= Total solar panel Area (m²)

r= solar panel yield (%)

H= Annual average solar radiation on tilted panels (shadings not included)

PR= Performance ratio, coefficient for losses (range between 0.5 and 0.9, default value = 0.75)

4. Power Generated from Wind

$$P = \frac{1}{2}\rho A v^3$$

….. Equation No. 5

Where

ρ = Density of Air (kg/m^3)

A = Area the wind is passing through the will mill

v = Wind Velocity (m/s)

5. Power Generated From Solar

$$P = V_{OC} \times I_{SC} \times FF$$

…. Equation No. 6

Where V_{oc} = Open circuit voltage

I_{sc} = Short circuit current

FF = Fill factor (Degree of squareness of I-V curve)

III. RESULT

For estimation of output power recorded data are analyzed. By using this data we can find out the results. For finding out the result we can take the reading from station installed on the location after every one hour measure solar radiation, wind speed and temperature and the corresponding output voltages. Average hourly data were calculated from these reading which are compared with each other. The measurements for wind energy potential were realized at Indore. The wind speed distributions for 50m level height are measured which was found to be 3m/s and the solar radiation received is 5.36 (kW/m2/day).

The total possible output voltage from both solar and wind turbine for this model, when working at full input is approximately 20 Volt (when loaded). And output power is approximately 14 Watt. However the wind turbine may not work at full capacity due to physical constraint (wind speed) as it is location specific. So the output from this model is approximately 14 Volt and output power is around 11 Watt.

Result Tables

Solar Panel Output

Table No.1 Solar Panel Output

Time	Open Circuit Voltage (in Volt)
6 AM	9.7
7 AM	10.5
8 AM	15
9AM	17.6
10 AM	20.3
11 AM	21.3
12 PM	21.3
1 PM	21.3
2 PM	21.3
3 PM	21.3

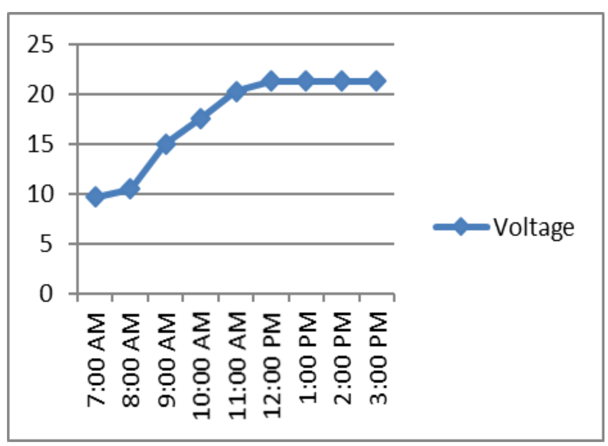
Wind Turbine Output

Table No.2 Wind Turbine Output

RPM	Output Voltage (in Volt)
1890	0.5
2748	0.98
3570	1.6
4790	1.75
6500	1.97
7862	2.12
8569	2.48

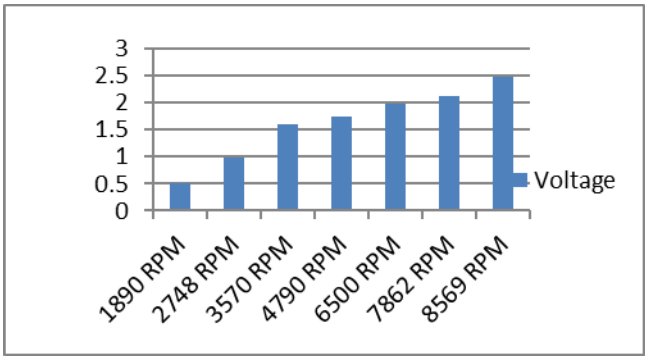
Result Graphs

Solar Hourly Data



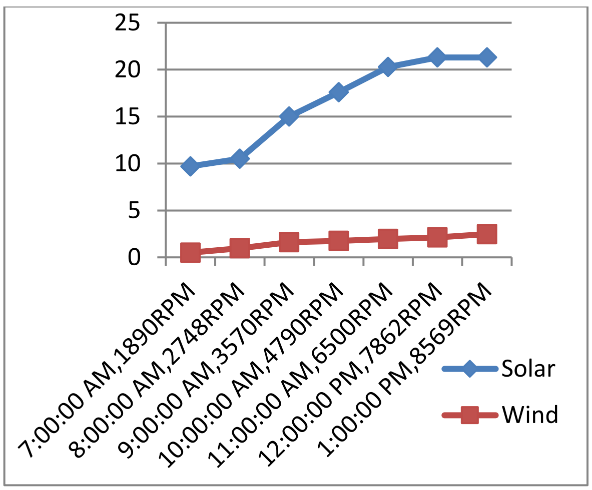
Graph 1 Solar Panel Output Voltage

Wind turbine



Graph 2 Wind Turbine Output Voltage

Solar- Wind Hybrid Output



Graph 3 Solar-Wind Hybrid Output

The total possible output voltage from both solar and wind turbine for this model, when working at full input is approximately 20 Volt (when loaded). And output power is approximately 14 Watt. However the wind turbine may not work at full capacity due to physical constraint (wind speed) as it is location specific. So the output from this model is approximately 14 Volt and output power is around 11 Watt.

IV. CONCLUSION

This project provides a standalone power generation system, which can be employed at various places to meet the requirement. The use of renewable sources like wind and solar power makes the model environment friendly. Use of such hybrid power generation not only decreases the demand of non renewable sources but also enhance the use of green energy to meet day to day requirements of the ever increasing population. This project model can be implemented in rural area where the power cut off is regular. With some modification in wind turbine part and increasing the number of solar panels wattage this model can be utilized as standalone system especially in offshore or onshore, where the speed of wind is adequate. By using a Power Converting Unit, this model can be utilized as a Grid-tie power system.

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