ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijareeie.com

Vol. 6, Issue 5, May 2017

Performance Analysis of Solar Module with Climatic Data

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ABSTRACT: The Sun's radiation can be converted to Electricity through Photovoltaic module. The solar module efficiency relies on sun intensity. If the intensity is more, then efficiency is more. Thus the incident of Solar radiation should be forming a right angle to the Solar module to generate more electricity. This paper describes in detail about how the modules should be mounted on structure and various factors. For the same load and weather conditions, performance varies when modules in different facing. The performance of the photovoltaic system depends on geographical location and different technology of the solar module. Analyzing the climatic data, how weather conditions affect the performance of the Solar modules.

KEYWORDS: Photovoltaic System, Irradiance, Tilt angle, Azimuth angle, Climatic data.

I. INTRODUCTION

Photovoltaic (PV) materials convert light energy into electrical energy called "Photoelectric Effect". Solar cells or Photovoltaic cells are electricity producing equipment made of Semiconductor materials like Silicon. PV cells can vary in sizes and shapes. They are combined together to form PV modules. Modules intern combined and connected to form PV arrays of different sizes and power output as shown in figure 1. The size of an array and the type of the module depends upon the amount of sunlight available in a particular location and needs of the consumer. PV modules have Glass superstrate, Tedlar substrate, encapsulant, Aluminium Frame, Junction box, connector cables [1].

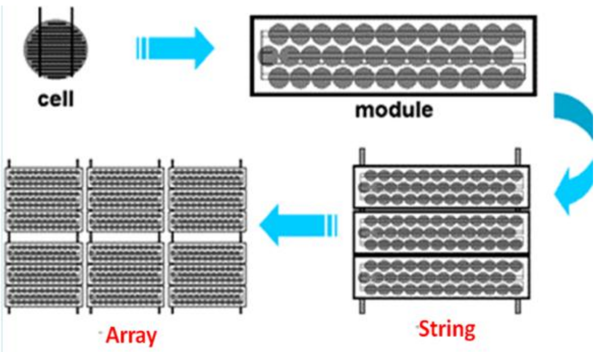

Fig. 1 Panel formation terminology

To estimate power from the solar modules, a suitable model required. Fig. 2 shows the typical Block Diagram of solar Photovoltaic system. A Charge controller is used to prevent overcharging and prevent against the overvoltage. It prevents from completely draining a battery. We directly connect DC Loads. If we want AC loads to connect the inverter before that. The Inverter converts DC to AC. Component ratings to be selected based on output requirement.

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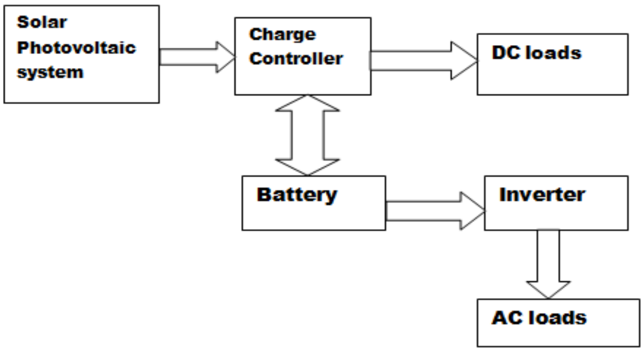

Fig.-1 Typical Block diagram of Solar Photovoltaic System

The output of the solar module should be depending upon the climatic conditions such as solar radiation, temperature, Humidity and wind speed. While considering the site these conditions should be noted down from various measuring instruments. The Solar module output decreases shading of the panels. Solar panels having a longer life span, but their performance drops significantly if a large or small portion of the panel exposed to direct shade for a period of a time.

II. INSIGHT ABOUT SOLAR CELL

A. Performance Evaluation of Solar Cell

Solar panel collects solar radiation from the sun and effectively converts that energy to electricity. Solar panels are made up of many individual solar cells, and it operates similarly to large semiconductors and utilize a large-area p-n junction diode. N layer made with Silicon and Phosphorous, P layer Silicon and Boron. When the solar cells act like p-n junction diodes, it converts the vitality from sunlight into usable electrical energy when exposed to sunlight. Sunlight striking the surface of the panel electrons will be generated and opposite side holes will be created. The Flowing of electrons causes electricity as shown in fig 3.

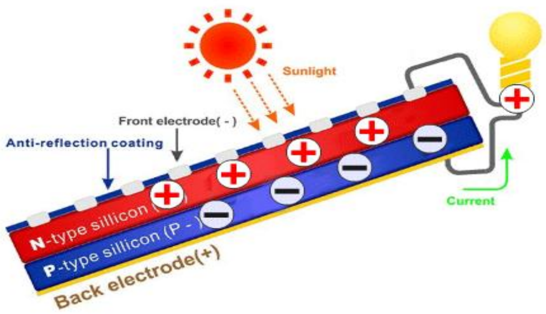

Fig. 3 Electricity generation in PV cell

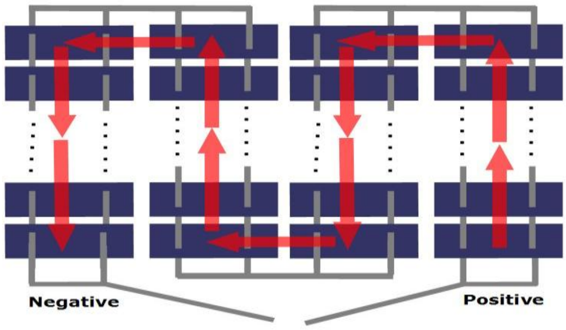

Fig 4 wiring diagram of the panel by connecting cells

Solar cell in the solar panel can generate approximately 0.5V to 0.6V, so if we combined in series 36 cells we get around 18 volts. In general, more solar cells on each panel the more electricity they can produce. The solar cell is to be the micro thickness, connecting solar cell in series, we can increase the voltage by KVL and by connecting solar cell in parallel, and we can increase the current. So depend on capacity, we can connect Solar cells [1]. Wiring diagram of connecting cells as shown in fig 4. The upper layer is taken as positive and the lower layer is taken as negative and both combine taken a required output

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The amount of electricity generated by the panel is found out by multiplying the rated voltage and the rated ampere. I.e. VOLTS*AMPS = WATTS.

Solar cells: Energy conversion factors

Cell efficiency: the conversion efficiency of PV cells is a proportion of sunlight that the cell converts to electrical energy.

Conversion efficiency, $\eta = \frac{Poutput\ (electric\ )}{pincident\ \ (light)}$

Power generated, $P_{max} = V_{mp} * I_{mp}$

Fill factor: fill factor is the ratio of maximum power and the product of I_{sc} and V_{oc}.

$FF = \frac{(Imax * Vmax\ )}{Isc * Voc} = \frac{Pmax}{Isc * Voc}$; typical values = 0.70 to 0.75

P_{inc} = incident light energy = $100mW/cm^2$

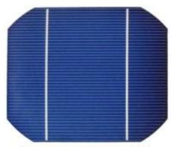
Effect of temperature = -0.45% / $^{\circ}C$

B. Solar Panel Technologies

Mono-Crystalline Technology:

This type of solar cell consists of a single layer of silicon. The cost of the panel is higher because pure silicon is used; it is the most expensive solar cell to produce [2].

1) Crystalline framework is homogeneous.
2) Produced by growing high purity, single crystal Si rods and slicing them into thin wafers.
3) Most commonly made by the Czochralski process Cell has an even, smooth look.

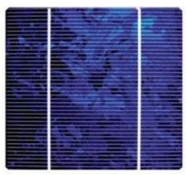


MONO CRYSTILLINE

Poly-Crystalline Technology:

To make polycrystalline silicon cells consist of liquid silicon. It is less efficient, because some degree of degradation of the silicon crystals. However, this technology is easier and cheaper to manufacture [2].

1) Each cell is composed of a block of multiple crystals, rather than out of a single silicon crystal.
2) Cells have a distinct look grainy or mosaic.



POLY / MULTI CRYSTILLINE

Thin film Technology:

The Thin film solar cell uses semiconductor layers that are only a few micrometers thick. The cost of thin film is lower because lower the material cost. It is less efficient than the other types of silicon. It has advantages because it is placed on a flexible material, prepare things like roof tiles. These materials have positive temperature co-efficient, so we can use in high temperature conditions. These include the following [2]:

1) Arsenide
2) Copper indium Diselenide
3) Cadmium Telluride

C. Tilt Angle and Azimuth Angle

While installing the solar module, latitude and longitude of the particular location should be considered. According to that Tilt angle of the module is obtained. It needs to point them in the direction that captures the most sun. But there are a number of variables in figuring out the best direction. It is designed to help to find the best placement for the solar panels in the situation.

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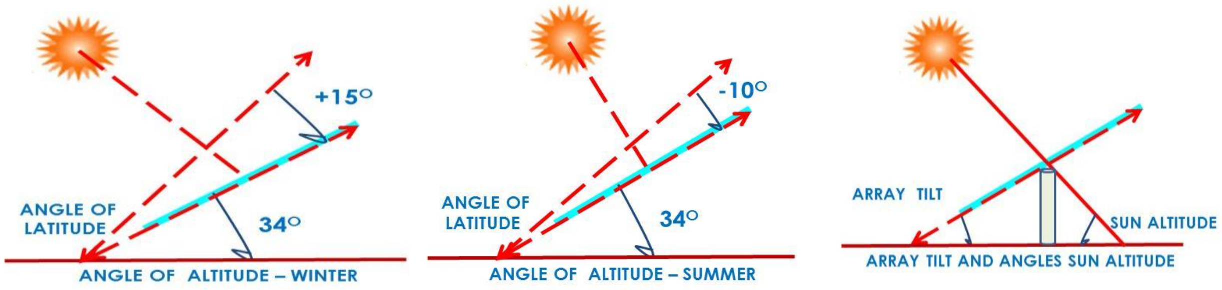
Vol. 6, Issue 5, May 2017

a) It is the angle between array and horizontal surface, which gives maximum solar irradiation
b) Solar panels should always face true south if you are in the northern hemisphere, or true north if you are in the southern hemisphere



(a) (b) (c)

Fig 5. Angle of altitude different season

The solar panel performance gets stirred by the tilt angle and azimuth angle. Therefore, there is need to have the optimum tilt angle specific to the local latitude. According to the Duffie and Beckman the optimum angle is calculated as below [3]:

$$B_{opt} = (4 + 15deg) \pm 15\ deg\ (where\ 4> is\ local\ latitude)$$

With varying weather conditions, i.e. in the winter and summer season, the tilt angle is to be increased and decreased respectively. Azimuth angle defines the direction of the Sun. It is considered as zero since the panels are mounted facing south in the northern hemisphere [4].

III. CLIMATIC DATA ANALYSIS

An analysis of the solar irradiance, wind power, Temperature and Humidity for Bengaluru, Karnataka India is presented. The analysis of local weather data patterns shows that solar power, wind power and Temperature can remunerate well for one another, and can furnish estimable utilization factor for renewable energy applications [8].

To measure the climatic data using few instruments those are:
a) Solar Power Meter
b) Anemometer
c) Temperature and Humidity meter

Solar Power Meter It Measures the Intensity of the solar radiation striking the earth. That is used to calculate overall energy, efficiency and placement of solar systems. The STC value for irradiance is 1000 watts per square meter [W/m^2]. Its value varies from 0 W/m2 to 1250 W/m2. The 1000 W/m2 value represents full sun or Peak sun.	
Anemometer It is a device used for measuring wind speed in the atmosphere in m/s or km/s.	

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Temperature and Humidity meter This meter senses temperature and humidity in atmosphere and it measures minimum, maximum real time values of room temperature and humidity	

IV. RESULTS AND DIISCUSSION

Consider a solar module having a bellow specification:

Maximum Power(Pmp) = 10WP
Open Circuit Voltage (Voc) = 21.6V
Short Circuit Current(Isc) = 0.659A
Voltage at maximum power(Vmp) = 17V
Current at maximum Power(Imp) =0.588A
Irradiance = 1000 W/m^2
Cell temperature = 25 °C

a) During installation, we need to select a suitable place by determining geometrical conditions. Then we need select suitable tilt for the solar panel. The angle should be calculated based on the latitude of the particular location.

Table 1

South facing	**15 degrees**	
	Voltage	Current
Without shading	17V	0.3A
With Shading	16V	0.14A

Table 2

North facing	**15degree**	
	Voltage	Current
Without shading	15V	0.26A
With shading	12V	0.1A

India is situated in the Northern Hemisphere (above the equatorial region). So Panels should be facing to south to get maximum output. Table 1 shows that when we face panel to the north getting results less than facing in the south. Thus, comparison table 1 and table 2, Panels should be facing south to get the maximum Sun shine.

b) Climatic Result

At a particular time, we measure Solar irradiance, Wind Speed, Temerature and Humidity, at the same time noted down the Panel Output readings as Voltage and Current as shown in Table 3.

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Table 3 Climatic Data

Sl no:	Time	Solar Radiation W/m^2	Temperature In °C	Humidity In %	Wind speed In m/s	Panel output	
						Voltage In V	Current In A
1	10-30	800	34.0	49	0.1	12	0.2
2	11-00	1040	32.8	52	0.7	15	0.3
3	11-30	700	34.2	60	0.8	14	0.2
4	12-00	336	33.1	46	0.4	12	0.1
5	12-30	1070	33.2	45	0.3	15	0.4
6	13-00	1010	33.6	47	0.3	14	0.3
7	13-30	200	32.6	46	0.6	12	0.1
8	14-00	950	33.3	44	1.5	13	0.44
9	14-30	249	33.4	45	1.3	12	0.2
10	15-00	176	32.8	49	1	12	0.1
11	15-30	720	33.8	44	1	14	0.35

c) Graphs

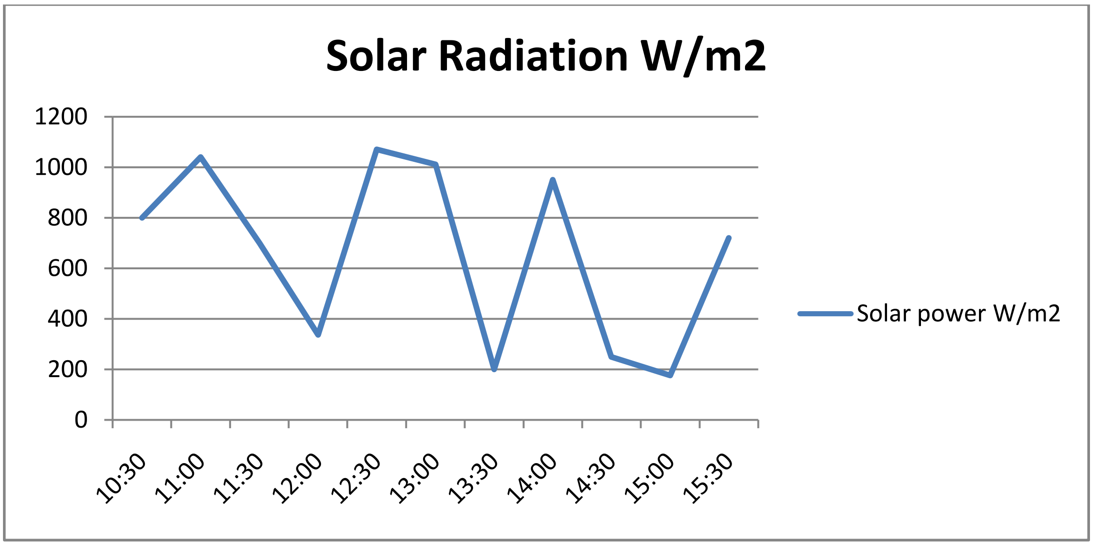

Fig 6 Solar Radiation v/s time

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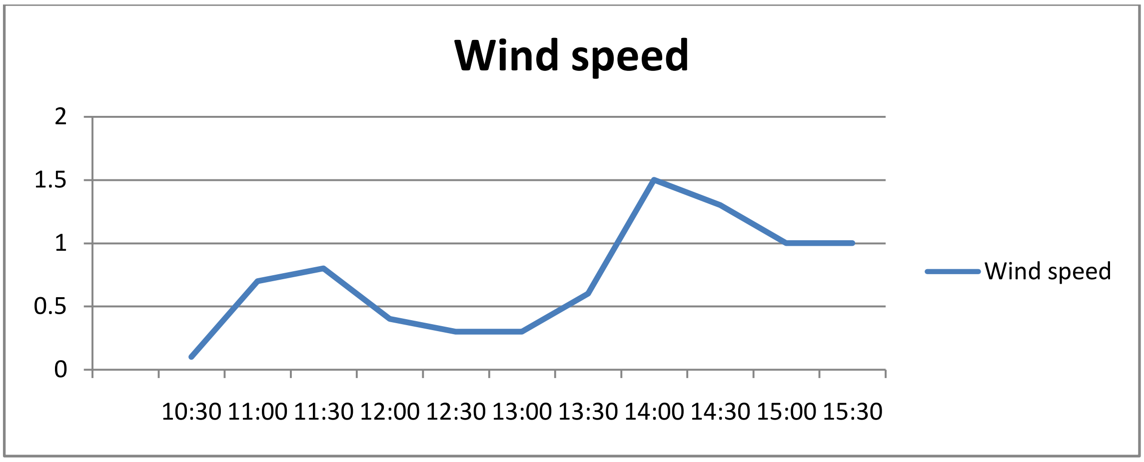

Fig 7 Wind speed v/s time

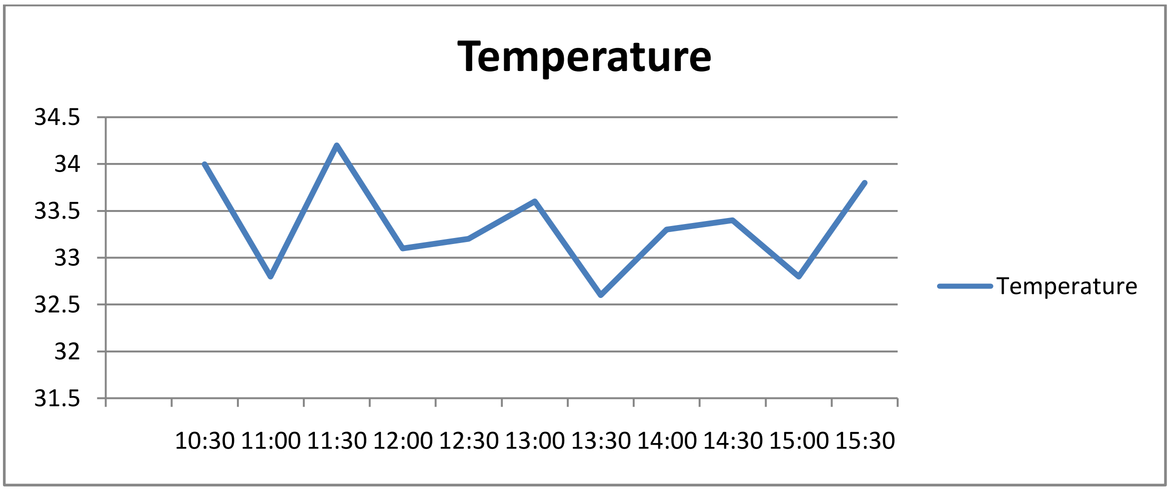

Fig 8 temperature v/s time

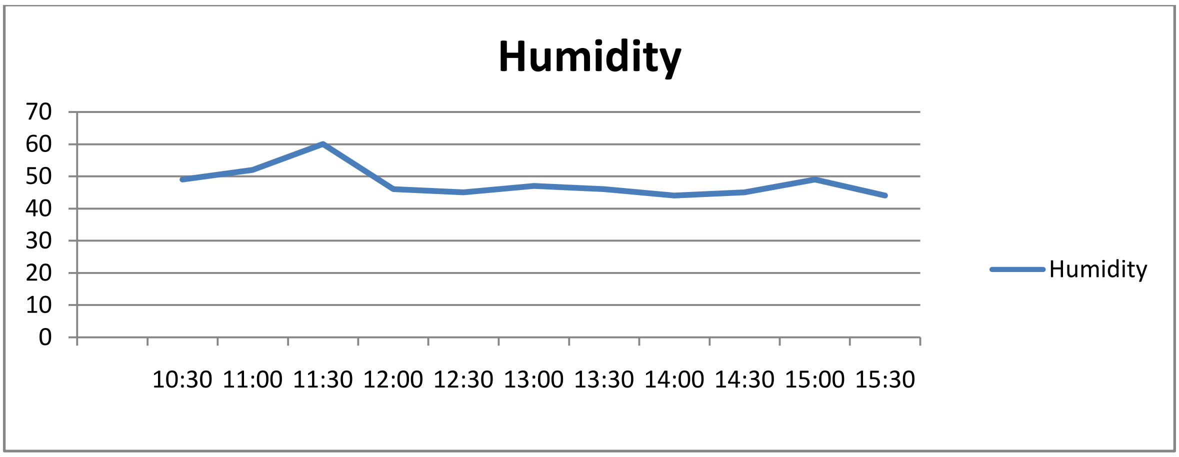

Fig 9 Humidity v/s time

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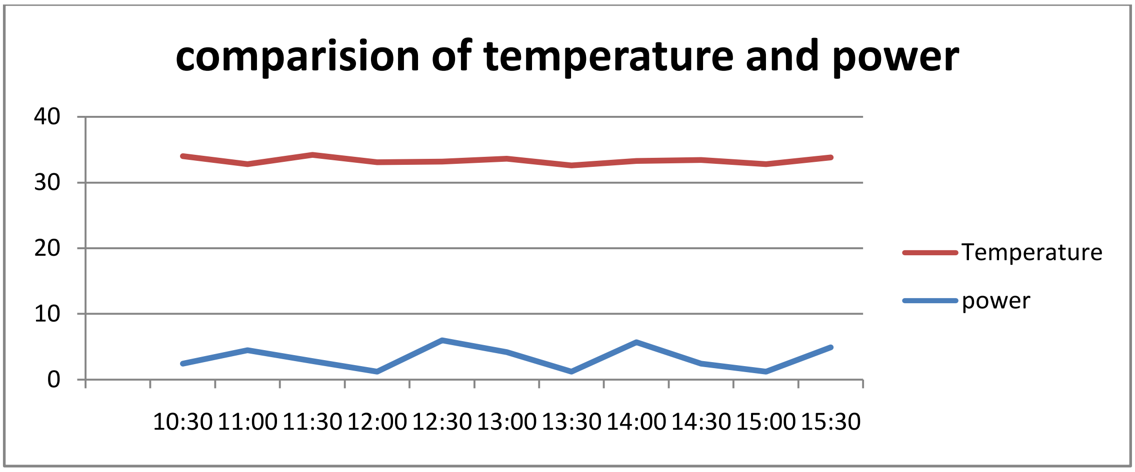

Fig10 comparison temperature and power v/s time

Solar powerfully depends upon the irradiation, absorbing surface and sunlight. Absorbing surface and sun should be vertical to each other. Solar cells are sensitive to temperature, increases in temperature decreases the power generating capability shown in fig 8. Mono and Poly crystalline modules are negative temperature coefficient, thus when temperature increases power decreases. Thin film modules are Positive temperature coefficient, thus temperature increases performance also increases. So thin film technology used in high temperature regions.

Increase in temperature causes slightly increase in current in the solar cells and decreasing in voltage by a greater amount. The result is less power produced as shown in table 3.

Relative humidity affects the efficiency of Solar panel. Efficiency of Solar panel is high during low relative humidity and also performance is high. Figure 6 shows that humidity varies with time. During Morning and Evening time humidity will be more, thus Performance of the solar panel is minimized. During the peak time, humidity will be less, thus Performance of the panel is maximized. That's why we are getting maximum output during peak time.

Wind Speed is also considered for performance. At higher Wind speed, the air temperature decreases and output increases, So Wind Speed can help solar panels perform more efficiently. Thus, during Installation, solar panels should be fixed above the surface level that is 3 or 6 feet, this allows the wind to flow between the solar panels and the roof.

Finally, to get Maximum Output from the Solar panels we have better climatic conditions. Having an optimum Temperature, more wind speeds, low relative humidity and high solar insolation level.

V. EXPERIMENTAL SETUP

A 10Wp Solar panel is taken for analysis purpose, it is connected to the 12V Charge Controller, and it helps to prevent the battery from overcharging, discharging and increases the life of the battery. It is connected to the battery and required DC load. If we want AC load, 12V Inverter connected between them. By using DC Volt-Ampere we took input readings.

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Fig. 1 Experimental setup

VI. CONCLUSION

The Results obtained from the analysis of the solar panel with respect to the different facing of the modules obtaining a high energy output from the PV panel. However Panels should be placing true south to get required energy demand. Since, we can generate sufficient power from solar energy. The solar efficiency depends upon the climatic conditions like solar radiation, Temperature, wind speed and Humidity. These factors are to be considered during site selection. Studied operation of the solar cell and various technologies involved in that.

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