Experimental Analysis of Factors Affecting the Power Output of the PV Module

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ABSTRACT

Energy is the driving force in all the sectors as it acts like an index of standard of living or prosperity of the people of the country. However heavy dependence on fossil fuels leads to global warming, hence there is a need for the use of clean, sustainable, and eco friendly form of energy. Among the various types of non-conventional energy solar energy is the fundamental as it is abundant, pollution free and universally available.Even though the main input to the PV system is the solar radiation still there are other factors which affects the efficiency of the pv module. In this paper real time experiment has been conducted to analyze the effect of various factors like irradiance, temperature, and angle of tilt, soiling, shading on the power output of the pv module. Temperature is a negative factor which reduces the efficiency of the module and can be reduced by various cooling arrangements. Presence of dust particles and shading obstructs the incident solar radiations entering the panel and the effect is seen in the iv and pv curve .For better performance solar tracking at maximum power point is suggested to improve the power output of the pv module.

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1. INTRODUCTION

Solar energy is a very attractive renewable energy source due its various advantages. Light weight, free, sustainable, less complex structural requirement, noise free operation, absence of large rotating machinery, easy installation, application close to requirement, less maintenance are some of its advantageous features for gaining attention in the energy sector in comparison to fossil fuels. The consumption of fossil fuels causes climatic changes due to the release of carbon-dioxide to the atmosphere. An array of solar panels makes photovoltaic system which converts solar radiation into electricity. Each panel is made of modules and each module are made of solar cells which are mostly semiconductors. Fill factor and efficiency are the estimating factor for knowing the capacity of the pv cell. Studies shows that only a fraction of solar light striking the module is converted into electrical energy and the rest of the absorbed energy is converted to heat which cause increase in the junction temperature [1]. El Hadi Chahid studies the influence of various factors on the iv characteristics of pv cell. These are like number of measurements taken, cell voltage range, series, parallel and hybrid combination. He used Newton Raphson method to calculate the parameters and compared it with the manufacturer data sheet [2].

It is seen that pv module efficiency decreases with increase in temperature [3].The cells will also exhibit long-term degradation if the temperature exceeds a certain limit [4]. The cell efficiency is known to decrease due to non uniform temperatures across the cell [5],[6]. Solar tracking is also an efficient way of improving the efficiency of the module. Load matching is required for extracting maximum power from a pv module. There are two ways of tracking passive tracking where the module orientation changes slowly as per the set path and active tracking which is based on the use of optical sensors. As stated by Mousazadeh et al. [7], the use of sun-trackers cause an increase in the energy collected from sun by 10% to 100% which depends on geographical conditions and time period. Recently a 45-day experimental study conducted by researchers concludes the fact that by the use of sun-trackers, the amount of energy produced significantly increases by 14–20% [8]. The same results were obtained by Eke and Senturk and their results demonstrated than after one year of operation, about 30% more energy is obtained by a dual-axis sun tracking system than the latitude-tilt fixed system [9]. Dust deposition on the surface of solar modules can cause two different effects i.e. firstly by reducing the amount of solar radiation by decreasing the transmittance of the glass cover and secondly by reducing the concentrating ability of the concentrating optical system [10]-[12]. Dust deposition depends on various factors like material, size, wind speed, humidity, tilt, geographical location, seasonal effect etc [13]-[16]. In a partially shadowed cell the shadowed portion does not produce any electrical power where as the unshaded part produces power. The voltage generated from the illuminated part forward bias the parallel rectifier. As the shadowed area is small a large circulating current flows which causes excessive heating. Thus the damage caused by shadowing can be reduced by using bypass diode. The bypass diode provides an alternative path for the load current and hence the damage can be reduced. Even due to shading effect multiple maximum power points exist on the PV curve [17]. Thus the pv user generally wants the pv system to operate at its highest energy conversion output by operating at maximum power point irrespective of any environmental changes [18].

2. FACTORS AFFECTING THE OUTPUT PERFORMANCE OF THE PV MODULE

Studies show that that there are several factors which affect the power output of pv module. While designing a PV system these factors should be given importance for better performance. The analysis was carried out in real time basis on the month of March in the terrace of campus 3 block A, school of electrical engineering KIIT University, Bhubaneswar, India. A 37 watt Photovoltaic module of make Vikram Solar was used for the experiment purpose. The module specification is given as below. A solar meter was used to measure the irradiance level. Resistance temperature detector was used to measure the temperature of the pv module. A voltmeter and ammeter of dc type was used for measurement of voltage and current. A rheostat was connected for varying the resistance which acts like a load. For the soiling and shading test two nos of pv modules of same rating was used so that the output of dusty panel was compared with that of the clean panel and unshaded panel with shaded one..The output characteristics of solar cells are expressed in the form of I-V curve and P-V curve. The module specification is given as below.

Table 1. Specification of the Photovoltaic Module

Parameter	Specification
Maximum power	37 watt
Open circuit voltage	21.8 volt
Short circuit current	2.40 amp
Maximum Voltage	17.20 volt
Maximum Current	2.20 ampere
Area	0.367m^2
Length	66.5 cm
Width	55.2cm

Figure 1. Real time experimental setup for the analysis of various factors affecting pv module performance

3. RESULTS AND ANALYSIS

In this experimental analysis various factors like irradiance, temperature, angle of tilt, soiling and shading are taken to see the effect of these various factors on the power output of the pv module.

3.1. Effect of Irradiance

As the Sun's position changes throughout the day irradiance also keeps changing with it. It is found that maximum irradiance is around 12:00 to 1:00 pm and slowly it goes on decreasing. Keeping factors like temperature and spectral content constant both short circuit current and open circuit voltage increases with increase in the intensity of radiation. As the no of photons striking the module increases photon generated current also increases.

Table 2. Values of Maximum power and Irradiance at regular time interval

Time in hours	Irradiance (watt/m^2)	Maximum Power (Watt)
10:00-11:00	700	14.4
11:00-12:00	800	15.8
12:00-13:00	842	16.4
13:00-14:00	756	15.4
14:00-15:00	584	11.6
15:00-16:00	352	6.4

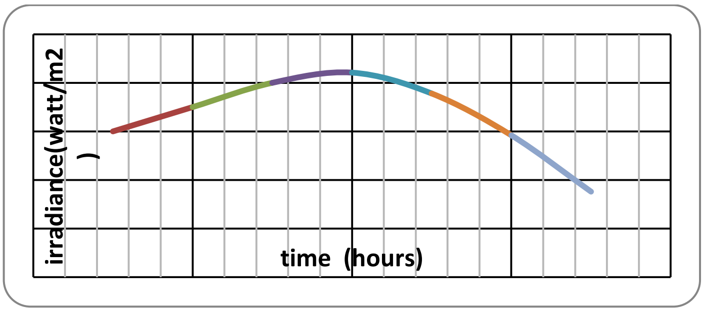

Figure 2. Shows the variation of solar irradiance with time of the day

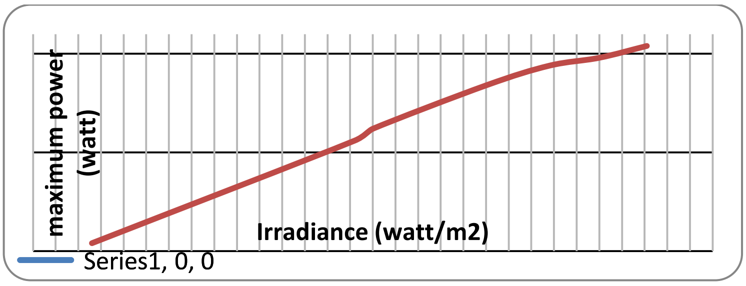

Figure 3. Shows maximum power increase with increase in irradiance

From the real time experiment conducted from morning 10 am to 4 pm it was found that during the early hours the value of solar irradiance was less where as it reached its peak at around 12:00 to 1:00pm and again with the sun's position the value decreased. Maximum power calculated was also found to increase with the increase in solar irradiance.

3.2. Effect of Temperature

With the increase in solar insolation photon generation rate increases as there is a reduction in the band gap. The total numbers of photons striking the module are not fully converted to electrical energy rather some amount of it is converted to heat thereby causing a rise in the temperature of the module. It is also found that short circuit current decreases slightly where as there is a remarkable reduction in open circuit voltage. Even temperature rise causes increase in reverse saturation current and decrease in Fill factor. Literature studies show that with the increase of 1K reduces photoelectric conversion efficiency by 0.2% to 0.5%. M.Mohamed Musthafa in his work stated that the temperature rises to maximum 39.6 degree while conducting an experiment from morning 8 am to 4 pm [10].

From the experiment, Figure 4 it was found that there is a difference in temperature for the module back surface and front surface of the module. Front surface is having higher temperature then that of the back surface. Table 3 shows a reduction in efficiency with increase in temperature. Even though at 12:00-1:00 pm the sun is at its maximum position and the irradiance level is high but due to the temperature effect the efficiency decreases by 0.56% for every degree centigrade rise in temperature. Hence cooling of modules are highly recommended to increase the efficiency. It is also observed that further decrease in temperature towards the end of the day doesnot increase the efficiency as the level of irradiance also goes down. By using either water cooling or forced air cooling the temperature of the module can be reduced at regularly intervals so that the system can be made to operate at the maximum allowable value causing less loss.

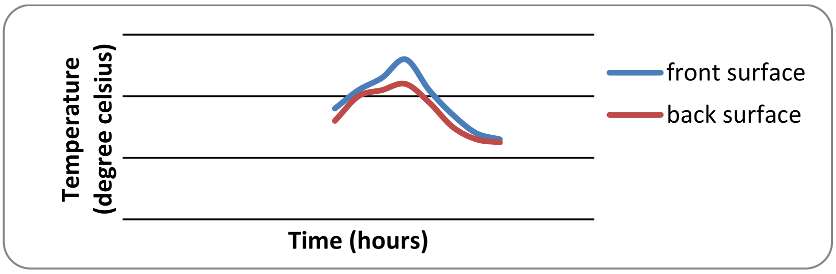

Figure 4. Shows the temperature of the module at both the surfaces

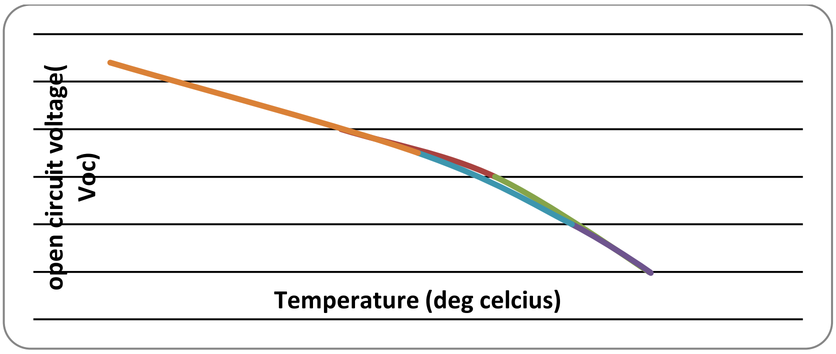

Figure 5. Shows the variation of open circuit voltage with temperature

Table 3. Efficiency at various temperatures

Time in Hours	Temperature (^{0}c)	Efficiency (%)
10:00-11:00	46	15.17
11:00-12:00	48	14.05
12:00-13:00	50	12.93
13:00-14:00	49	13.49
14:00-15:00	47	14.61
15:00-16:00	43	13.29

3.3. Effect of Angle of Tilt

Studies shows that angle of inclination plays a greater role then orientation. For optimal orientation the PV modules are kept facing south. The angle of inclination of the panel should be such that they match the latitude of the location minus the sun's declination i.e the angle between equator and the sun. In the real time experiment conducted the module was tilted at different angle and IV and PV curve was drawn. Several researchers have suggested that upto latidude 25 degree the summer angle is 2.3 degree and winter angle is 41.4 degree. This experiment was conducted in Bhubaneshwar with latitude angle 20.2961° N and was found to have highest efficiency at 45 degree tilt angle i.e 16.2%.

From Figure 6 and 7 it was concluded that module shows better performance in terms of power output at 45 degree angle of inclination. In this study manual tracking method was used where as using MPPT tracker the panel adjusts its tilt angle as per the position of the sun to receive the maximum incident photon. Studies show that there are various mppt methods for tracking but in this paper only the effect of angle of tilt on the panel power output is considered. From the table IV it was also found that module tilt at 45 degree gives the maximum power and a higher fill factor.

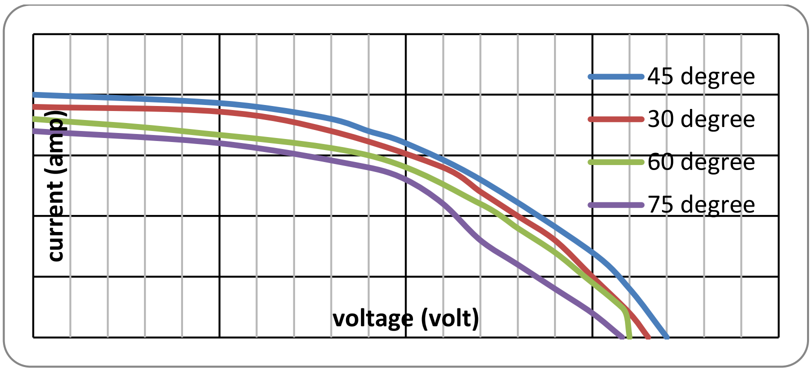

Figure 6. Shows the iv curve for various angle of inclination

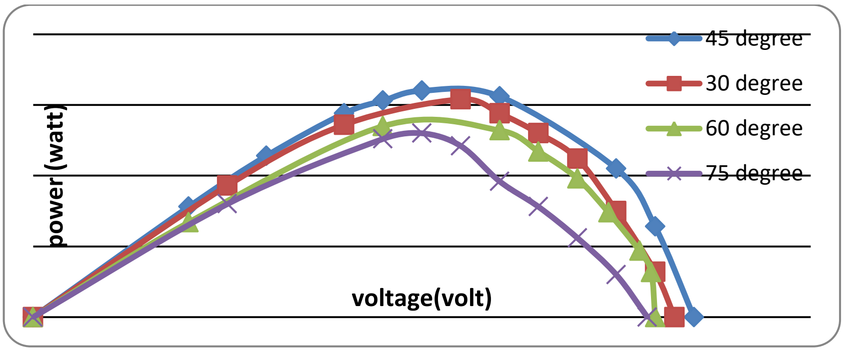

Figure 7. Shows pv curve at different angle of inclination

Table 4. Shows thevalueof Maximum power and fill factor for different titltangle

Angle (deg)	Maximu power (watt)	Fill factor
30	15.4	0.62
45	16.0	0.68
60	13.5	0.58
75	13	0.55

3.4. Effect of Soiling

Studies show that the performance of panels over long period of time without rain events is highly reduced due to dust accumulation. Not only duration of exposure but also frequency and intensity of dust affects the PV panel's power output. Dust particles blocks the incident photons reaching the PV cell, thus reducing the useful area of the pv module. In this paper an experimental test has been conducted and was found that dust accumulation greatly affects the short circuit current where as open circuit voltage has very little effect. Even various types of dust sample have been tested to see the effect of dust on the module performance and the result was compared with that of a clean module. Motasem Saidan et al suggested that the degradation in the output efficiency of PV module on soiling condition is 6.24% on an exposure of one day [11]. Some other researchers also suggested that module efficiency decreases by 15% due to dust deposition.

From Figure 8 it is clear that depending on the type of dust there is a greater change in the cell short circuit current but very less effect in the pv open circuit voltage.Panel efficiency also varies depending on the types of dust present and even time of exposure considering quantity factor. From the Figure 9 pv module with clay dust shows least efficiency. It can be concluded that presesnce of dust decreases the efficiency by 33%.

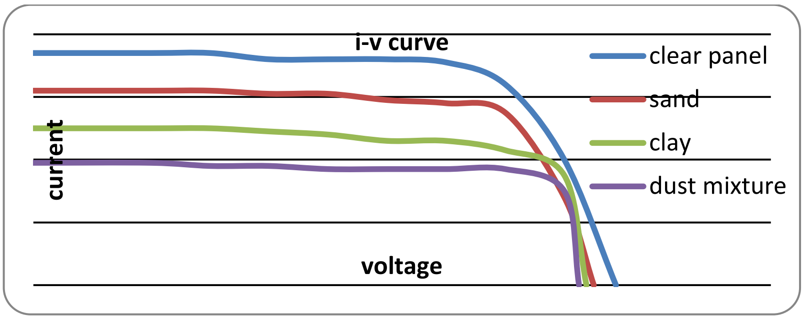

Figure 8. Shows iv curve for different types of dust

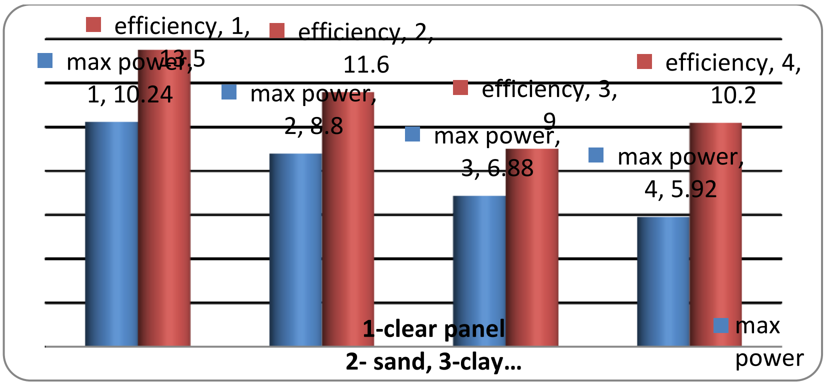

Figure 9. Maximum power and efficiency of various types of dust on pv module

3.5. Effect of Shading

Shade is one of the important parameter which affects the output performance of the pv module. Shading can be caused by various factors like presence of tall building, leaves falling, fog, cloud, dust particles, birds excreta etc. The shading effect can be broadly studied in two categories i.e soft shading and hard shading. It creates hotspots where temperature rises very high and can cause burning effect. Non-uniform shading causes mismatch in the current and hence power loss of the module.Sathyanarayan in his work has found out that under uniform shading condition the efficiency reduces by 0.15% for every 25% shading the panel [12]. Various studies suggest that shading is a negative factor for the performance of pv system. An experimental analysis has been carried out with different degree of shading like the module shaded for 25%, 50% and 75% and the result was compared with that of the clear panel without shading. For shading purpose measured cardboards were used.

Table 5 shows that with increase in the percentage shading the efficiency of the pv module decreases. Maximum power is obtained from pv module under no shade condition but with increase in percentage shading major changes in short circuit current is observed with marginal changes in open circuit voltage as shown in Figure 10 and Figure 11. From this experiment is it stated that with every 25% increase in uniform shading the efficiency of the module decreases by 3%.

Table 5. Efficiency at various temperatures

% Shading	Efficiency (%)
No shading	14.51
25%	14.23
50%	13.92
75%	13.63

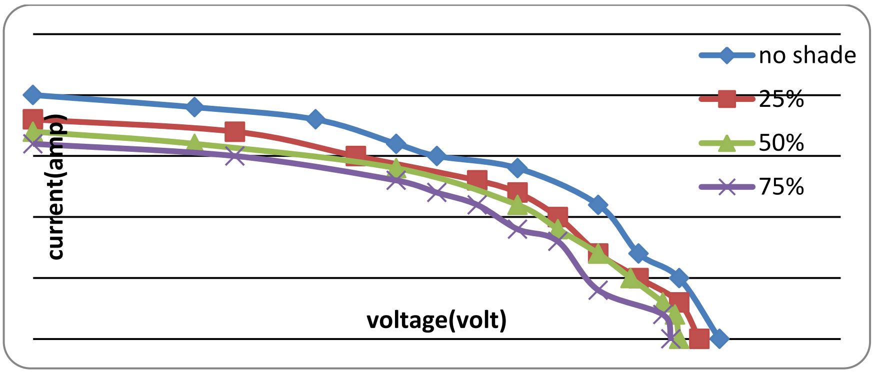

Figure 10. Shows iv curve for different shading conditions

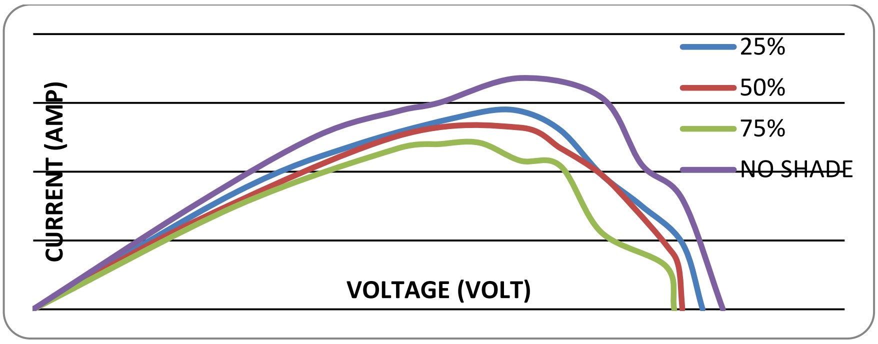

Figure 11. Shows PV curve for different shading conditions

4. CONCLUSION

With the increase in solar radiation striking the module maximum power increases which is experimentally obtained at around 12:00 to 1:00pm. But with increase in the photons reaching the module a part of this energy is converted to heat which cause rise in temperature. It is found that efficiency and power output decreases at high temperature. Water cooling or air cooling the panel at regular intervals can reduce this effect. Dust deposition does not largely affect the open circuit voltage of the PV module. At various irradiance levels open circuit voltage of dusty panel makes very small difference with that of the clear panel. The ratio of V_{oc} (dusty)/V_{oc} (clean) is around 99% for various intensity of light. Accumulation of dust on the PV module greatly affects the short circuit current of the PV module. Considering various irradiance levels it is found that the difference in current o/p increases with increase in light intensity from 220 watt/m^2 to 880 watt/m^2. I_{sc} for dusty panels is less than that of clear panels. A difference of 40-50% I_{sc} drop is observed for dusty panels. Shading is also one of the important factors which affect the module power output. From the IV and PV graph it is clearly seen that shaded modules have less power output in comparison to unshaded module. Even the module output is affected by the tilt angle and orientation. Amount of energy captured by the module can be increased by tilting the panel 15 degree steeper in winter and 15 degree less in summer with the latitude of the location. Even the output can be maximized by mechanically tracking the sun and orienting the module at various suns' position and electrically tracking and operating at maximum power point.

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