International Journal of Advance Research in Science and Engineering
Volume No. 11, Issue No. 11, November 2022
www.ijarse.com
IJARSE
ISSN 2319 - 8354

Effects of Ambient Temperature and Wind Speed on Performance of Mono crystalline and poly crystalline Solar Photovoltaic Module in Southern Rajasthan

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Abstract

Solar energy is regarded as one of the most significant renewable energy sources in the world since it will help to address the coming energy crisis. The most well-liked and widely applied solar energy technology is photovoltaic (PV). PV efficiency is still quite pricey and is only moderately efficient. PV efficiency is negatively impacted by high temperatures, making cooling systems for solar panels essential, especially in warm weather

In a specific location called Bhilwara, India, for the year 2021, the impacts of ambient temperature and wind speed on the performance analysis of a mono crystalline and polycrystalline silicon solar photovoltaic module have been examined. The research has been done by tracking how the efficiency of the modules varies with the surrounding temperature and wind speed. According to the findings, there is a significant positive linear link between module efficiency and ambient temperature as well as a tamely positive linear association between module efficiency and wind speed. While installing solar panels in Rajasthan, the generation of output power is impacted by the deviation from the standard test condition (STC). Numerous meteorological conditions have an impact on solar panels' low energy conversion efficiencies. The weather issues are caused by solar irradiation, the surrounding temperature, dust collection, and wind speed. This paper's primary objective is to comprehend how solar panels behave when wind velocity is a factor.

The operation of photovoltaic (PV) modules under real-world settings is crucial for obtaining an accurate estimate of their efficiency and power output, even though their efficiency is often specified under standard test conditions (STC). In addition to the immediate solar radiation, the temperature of the modules affects the PV conversion process. Climate variables and the technical specs of the PV panels both have an impact on module temperature. The current work is focused on the investigation of the temperature variation effect on the functioning of commercial PV applications at various weather conditions, taking into account the extensive theoretical background in the field to date. In particular, one year's worth of outdoor data from two commercial (m-Si) PV systems, one on a college rooftop open and second already in operation in Bapunagar Bhilwara, were gathered and assessed. Real wind speed measurements were also taken to evaluate the dominating influence of local wind speed on the thermal loss mechanisms of the PVs

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Introduction

Since the use of energy has become an integral part of our life, its supply should be secure and sustainable. The energyrequirement of the world is ever increasing. The increasing energy demands put a lot of pressure on the conventional energy sources. Therefore, there is a need for alternative energy sources which can provide us energy in a sustainable manner. While the temperature continuously rise the hot from March to June in the district, it goes down after mid-November it declines up to the month of January. In the year 2021 the minimum and maximum temperature recorded at Bhilwara centre was $4.^0$ C and $44.^0$ C respectively, while average temperature and humidity were recorded as 23.3 C and 65.0 percent respectively. A meteorological observatory is working at Bhilwara city which provides the information regarding climate of the district." The climate of the district is moderate and healthy,. The district has a hot dry summer and a bracing cold season. Generally the summer season starts in the district from March and continues up to June and winter season period runs from December to February every year. The rainy season in the district is generally runs between July to September. The 94 percent of total rainfall took place between this periods. The average rainfall of the district is 25.4inch. The obvious choice of a clean energy source, which is abundant and could provide security for the future develops- ment and growth, is the sun's energy. Apart from this, sun is also available to us indirectly in the form of wind energy. Wind energy globally has a successful alternative technology for electrical energy generation. Recently, there has been an enormous increase in the understanding of the operational principle of photovoltaic devices, which led to a rapid increasein the power conversion efficiencies of such devices. Solar cells vary under temperature changes which will affect the power output of the cell. The researchers also indicated that the desired efficiency of PV module can be achieved bychanging the ambient temperature around the PV module [1].Solar modules work best in certain weather conditions, but, since the weather is always changing, most solar photovoltaic modules do not operate under normal operating conditions. The performance of a PV system depends not only on its basic characteristics but also on the environment issue. One such environmental issue like the ambient temperature plays an important role in the photovoltaic electricity generation conversion process [2]. The solar modules are manufactured at STC, but when they are used for domestic purposes in a particular area, the environmental issues like ambient temperature as well as wind speed also affect the performance of the module for that particular locality and before installation we should take these parameters in mind to harness maximum power. The solar module's performance varies with actual location and prevailing environmental conditions to which they are subjected [3]. The photovoltaic output performance varies with atmospheric factors. Since the intensity of radiation is changing at every instant, it is obvious that energy production by the solar cells will also be changing. It has been observed that the power delivered by the PV systems at a certain instant is still very much a function of weather factors [4].

The efficiency of the module has dependency on the environmental parameters [5]. Meteorological data such as solar radiation, ambient temperature, relative humidity, and wind speed are accepted as dependable and widely variable renewable energy sources [6]. Different types of modules and arrays studied with different climates of different regions have been taken into account by researchers [7]. Among all major meteorological parameters, only ambient temperature and wind speed have been considered for the present study.

The specification given by the manufacturer does not actually give the accurate result while analyzing the per- formance of the photovoltaic (PV) system; thus the local environmental parameters must be taken into account

[8].In the north eastern region of India no such study has been done before to check whether the specification given bythe manufacturer met the actual environmental conditions. In our recent study we have considered the module of the solar home lighting systems which are actually installed in the premises of individual beneficiaries of rural and urban areas of Tripura by the government authority. Now, in actual case once the systems are installed, it is quite impossible to monitor the performance of the systems. Photovoltaic installations majorly get affected by cell temperature, soiling,and so forth. But the functioning of solar devices at anytime depends on the ambient variables also. Here for this reason an attempt has been taken to investigate how the performance of the photovoltaic module affected by the environmental parameters like ambient temperature and wind speed. In the recent study, a statistical analysis has been done to show how the ambient temperature and wind speed of the solar module are correlated with efficiency. It is seen from the analysis that there is a direct proportionality between ambient temperatureand solar photovoltaic module efficiency.

Solar energy is one of the most essential forms of renewable energy. Earth receives quantity of solar irradiation from sun is more than the consumption of humans need . Solar panel is a solar device which absorbs solar radiation from the Sun directly converts intoelectrical energy. All the solar panels are manufactured according to Standard Test Condition (STC) which is rated is solar radiation of 1000 W/m^2, panel temperature of 25 °C and light spectrum with an air mass (AM) is 1.5. But, when the solar system is applied for domestic purposes in certain regions, the solar panel performance will be impacted by the weather problems for the area. Therefore, the solar panel cannot perform actual performance as the specification given by the manufacturer.

Solar panel work great in specific weather conditions, but, due to the weather is constantly changing; majority solar panel cannot function normally under normal operatingconditions. Not only are the basic characteristics of solar panel will affect its performance, the weather problems also are one of the factors. Solar radiation, ambient temperature, dustaccumulation and wind velocity are the weather problems that perform significant role in the conversion process of solar panel.

In this investigation, the effect of wind velocity is focus on the performance of solar panel. Several researchers were focused to investigate the solar panel performance that affected by wind velocity effect. Latifa Sabri and Mohammad Benzirar [10] carried out the different amount of wind velocity results in solar panel operating temperature. When increases in wind velocity, the solar panel temperature decreased and enhance in power generated. Thisis because the high wind velocity can be dissipated more heat from the solar panel surface. In the work of S Mekhilef et al [11], environmental issues were suggested taken into consideration when applied solar application system. Dust accumulated, humidity and wind velocity as environmental issues that can be impacted the solar panel performance. The experimentalresult is showed the better solar panel performance when the higher wind velocity can be removed the temperature of solar panel. Hassan BS et al [12] state that the excess photon energy is dissipated in the form of heat impacted the performance of solar panels.

Jia Yang et al [13] constructed an experimental to investigate the impact of the wind velocity on the performance of solar array. The range of wind velocity is variable from 2 to 8 m/s. The result of the experimental is carried out the increasing wind velocity improved the power generated by solar panel. S Armstrong and WG Hurley[14] analyzed the heat transfer from the solar panel surface under varying wind velocity condition.

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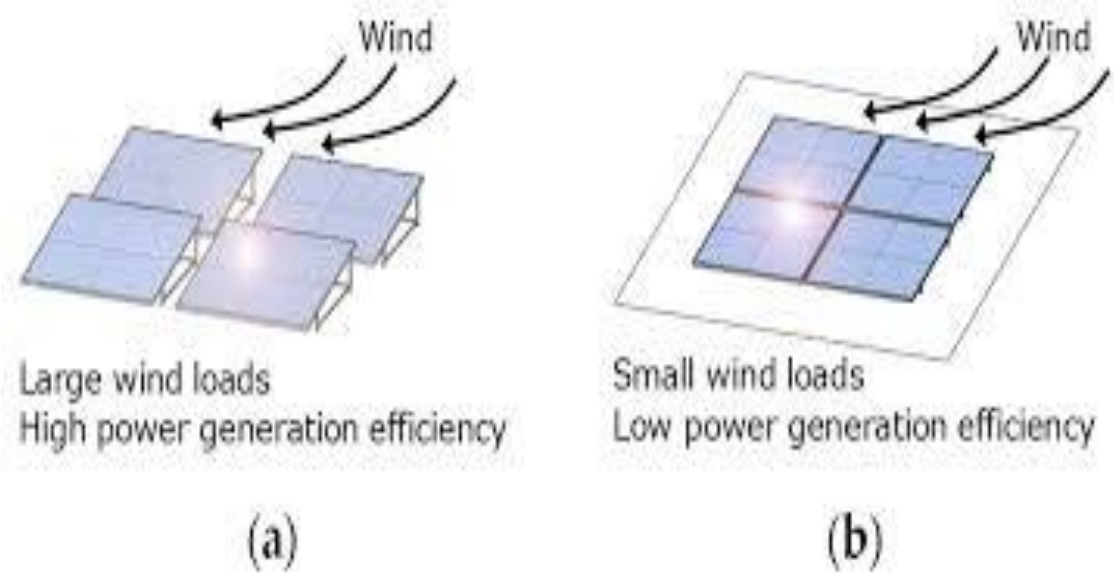
Experimental

Effect of Heat Transfer and Wind Velocity for Solar Panel Performance

During operation of solar panel, the excessive solar radiation and high temperature are the major factory cause the solar panel facing overheating. This result to solar panel produced less power output. It is also found that performance of solar panel is very sensitive to its operating temperature. The heat energy produced by solar panel and heat loss to the environment will be leading to equilibrium of solar panel operating temperature. This heatenergy can be transferred away by conduction, convection and radiation as shown in Figure .



The concept of conduction is carried out in the case of the two objects in contact; it is passed from the higher temperature to another lower temperature. Conductive heat losses that occurred on the solar panel are due to the thermal gradients between the solar panel and ambient surrounding condition the solar panel connected. In the one-dimensional in a rectangular coordinate, the following equation can be calculated by [15]

$$Q = kA\,(T_H\_T_C)/\,\Delta x \;=\; —\,kA(T_C\,\_T_H)/\,\Delta x = \;\_kA\Delta T/\Delta x \qquad (1)$$

Where, Q is represent heat transfer rate (W), K is the thermal conductivity [W/(m·K)], A is cross-sectional area (m^2), T_H is temperature of hot surface, T_C is the temperature of cold surface, ΔT is the difference between hot and cold temperature and Δx is thickness of the plane.

Convection heat transfer is transfer of heat by the movement of a fluid from higher temperature region to the lower temperature region. The lower temperature of fluid is move to the high temperature of fluid. Then, the lower temperature of fluid will take the place of the higher temperature. Generally, liquid and gas are the dominant form of this heat transfer. Convection heat transfer can be occurred either natural convection or forced convection. The natural convection is by density differences within fluid that happened due to temperature gradient and without any external source of support. Forced convection is movement of the fluid that is produced by an external source.By Newton's law of cooling, the rate of convective heat transfer can be calculated is given by [16]:-

$$Q = h \times A \times (T_S - T_f) \quad (2)$$

$$h = 5.7 + 3.8v \quad (3)$$

The quantity of Q (W) is known as the rate of convective heat transfer, h is represent the coefficient of convective heat transfer ($W/m^2°C$), A is the area of contact between the two materials (m^2), T_s is temperature of surface, T_f is temperature of fluid and v is represent wind velocity. In the Equation1, it can be seen the variation of wind velocity will play an important role on the wind heat transfer coefficient.

Radiation heat transfer is not similar as the concept of conduction and convection. Both conduction and convection is the transfer of heat via matter. While, radiation is transfer the heat in form of electromagnetic waves. Radiation is the heat transfer from the body according to the temperature; it increases as the body temperature increases. When the heat reaches to anothersurface of the body, they may be absorbed, reflected or transmitted. The emitted energy by a blackbody is given by Stefan-Boltzmann law as [17]:

$$P = \sigma \times T^4 \quad (4)$$

Where P is the PV panel produced as heat, σ is the Stefan-Boltzmann constant as 5.67×10^{-8} $W/m^2 °C^4$ and T is represent the temperature of PV cell in ºC.

Materials and Methods

During the study ,we used two commercial PV module with the characteristic shown in Table 1 below

Mono Crystalline solar panel(Cell Area)Power Loom company India

Max Power pmax	Max Power voltage	Max Power current	Short circuit current	Open circuit voltage	Fill factor
50W	20Volt	2.50Amp	2.60Amp	23.50Volt	0.7864

Poly crystalline solar Panel(Cell Area)Genius company India

Max Power pmax	Max Power voltage	Max Power current	Short circuit current	Open circuit voltage	Fill factor
40W	18Volt	2.30Amp	2.50Amp	22.61Volt	76.86

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We started our research by establishing the two modules of different technology in a fixed position relative to sun. The tilt angle and orientation are chosen so that panel collect as maximum of solar radiation as possible during the day. Then we calculate the power generated for each module separately experiment has been done with solar photovoltaic module mono crystalline, manufactured by M/S Solar Loom Ltd., India, as shown in Figure 1. A digital clamp meter(MextecDT-36T) is used to measure the short circuit current and open circuit

voltage. One digital thermometer hasbeen used to check the ambient temperature, anemometer to measure wind speed, and HTC LX-101A/102A solar powermeter to measure the intensity of the solar radiation asfollows:

The daily efficiency (η) of the PV module can be deter- mined from the following relationship:

$\eta = Pmax/\ S \times A$

$\eta(efficiency) = (maximum\ power\ output)/(Incident\ radiation\ flux \times area\ of\ collector)$

Where P = PV module power in watt and A = PV module area in square meter.

The values of efficiency were calculated for each day for one hour interval and from that the daily monthly average values were calculated. The daily monthly average values of ambient temperature were calculated by the digital thermometer.

For the present study the solar photovoltaic module wasplaced on the roof top of MLV Govt. college Bhilwara. General variation in efficiency with respect to ambient temperature and wind speed has been evaluated from (1) withthe required data. The values of ambient temperature and wind speed at an interval of 1 hour were recorded for each day and from that daily average and monthly average valuesof ambient temperature and wind speed have been measured.Table 1 shows the variation of monthly average values of ambient temperature and wind speed from Jan 2021to Dec 2021. Also monthly average values of efficiency of the photo voltaic module for the same period have been calculated as shown in Table 1. The aim of the present study is to find out the variation of efficiency of solar photovoltaic module with ambient temperature and wind speed. Dependency of efficiency of solar photovoltaic module on different factors except ambient temperature and wind speed are neglected for the analysis. The simple correlation coefficient R has been determined considering efficiency as dependent variable and ambient temperature and wind speed as independent variableseparately.

Figure 1 shows the variation of monthly average values of ambient temperature for the period of Jan 2021to Dec 2021. The ambient temperature varies with different months of the year throughout the period of the study for a particular area.

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TABLE 1: Variation of efficiency with ambient temperature and wind speed for the period from Jan2021 to Dec 2021.

Month	Ambient Temperature^{0}C	Wind Speed m/s	Efficiency Mon crystalline	Efficiency polycrystalline
Jan2021	16	1.1	14.34	11.52
Feb2021	19.4	1.2	15.22	12.14
March2021	32.9	2.0	16.82	14.12
April2021	33.8	1.9	17.14	14.52
May 2021	36.9	2.8	17.32	15.10
June2021	36.3	3.8	17.14	14.82
July2021	29	2.8	16.72	13.68
Aug2021	26.3	2.4	15.92	13.21
Sep2021	26.7	1.0	15.98	13.42
Oct2021	26.3	1.1	15.52	13.21
Nov2021	21.8	1.1	15.34	12.44
Dec2021	17.4	0.9	14.66	11.60

Result and Discussion

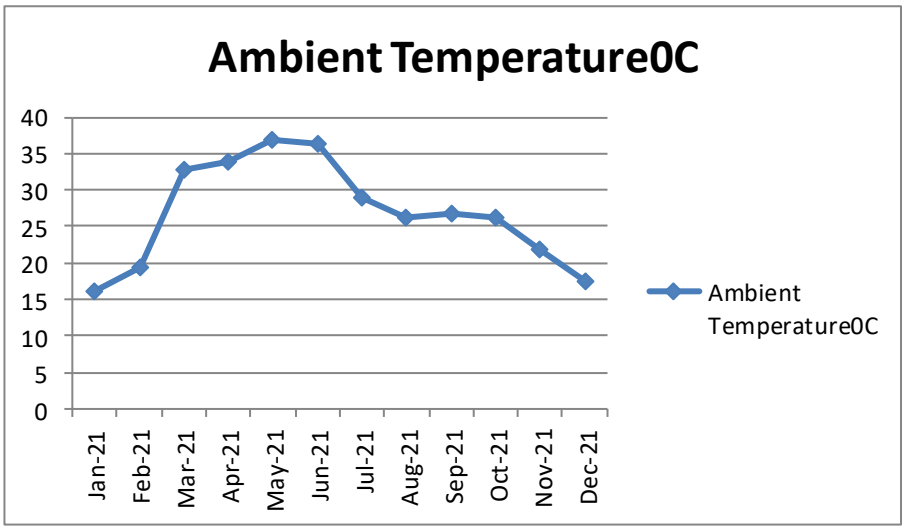

Figure- 1:Variation of ambient temperature for the period from Jan2021 to Dec 2021.

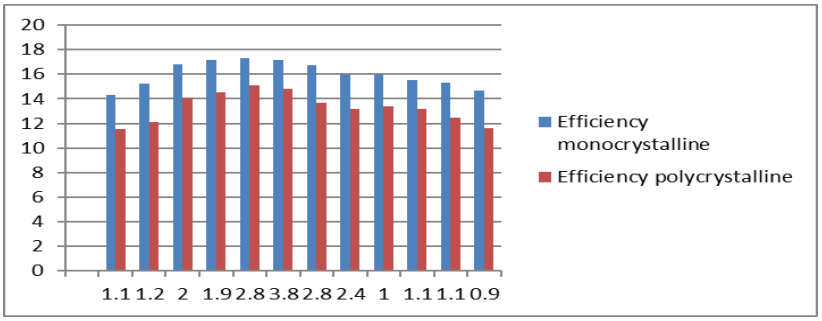

Figure- 2: Variation of ambient temperature for the period from Jan2021 to Dec 2021.

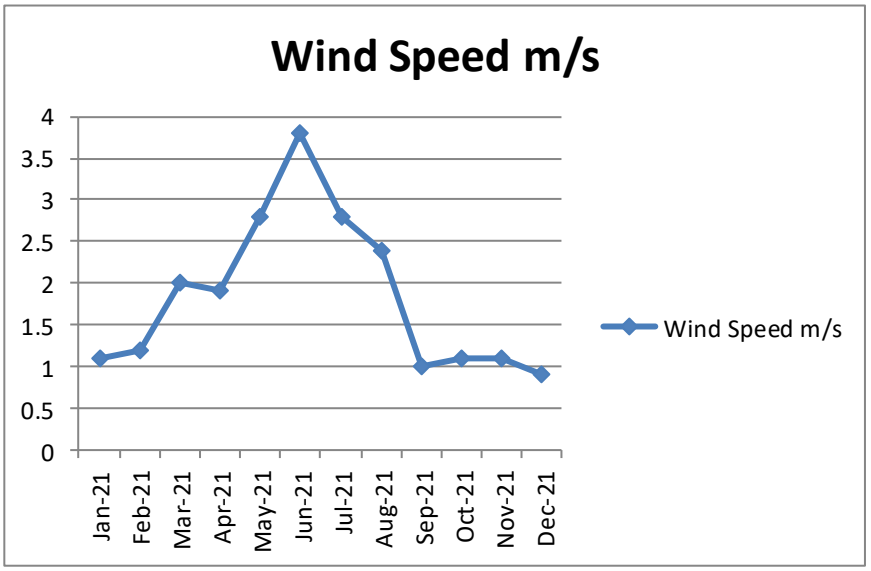

Figure- 3: Variation wind speed for the period from Jan2021 to Dec 2021

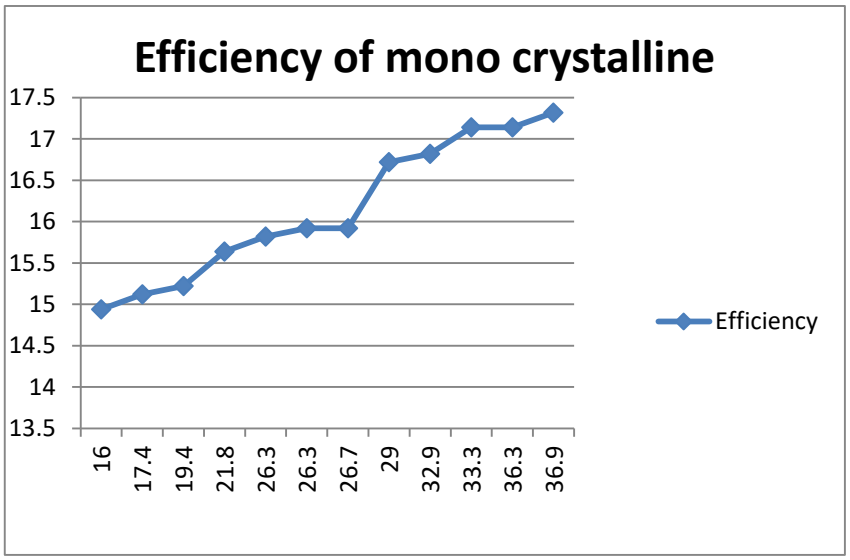

Figure- 4: Variation of efficiency of mono crystalline with ambient temperature

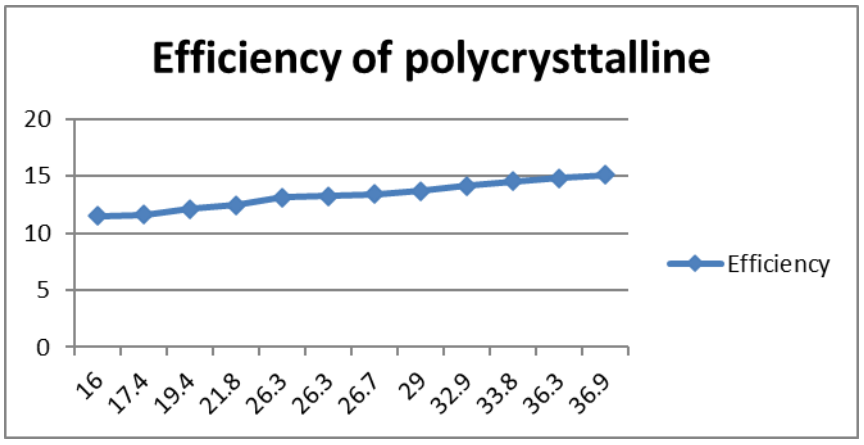

Figure- 5: Variation of efficiency of polycrystalline with ambient temperature

Figure 1 indicates the monthly average variation of ambient temperature. Figure 3 shows change wind speed for the period of Jan 2021 to Dec 2021. From the figure it is seen that the ambient temperature got highest value for the month of March, April, and May. The minimum values of outdoor temperature got in the month of December, January and February. The maximum values of ambient temperature are due to high solar radiation we get by sun. The temperature remains almost the same for the rest of the months from July to September. Accordingly, two distinct maximum values are observed in the month of July and March for wind speed. For April and May there is slight reduction in wind speed. For the period of August to February the values of wind speed remain almost the same.

In Figure 4 there is variation of estimating ambient temperature and output efficiency for mono crystalline solar panel. We noticed these physical quantities are closely related. It can be seen from this figure that the correlation between the module efficiency and ambient temperature is nonlinear. Figure 5 shows variation of efficiency of poly crystalline with ambient temperature. We also got change in capacity of panel to conversion efficiency for both types of technology. Study shows the variation of monthly average values of efficiency of the PV module against the ambient temperature for the period of 2021. It is seen from the pattern of the graph that the ambient temperature and efficiency are correlated with each other. There is a direct proportionality between the two variables.

Figure 2 shows the variation of monthly average efficiency of both type of PV module against the wind speed for the period of study. There is a moderate positive correlation between wind speed and efficiency.

Different linear and nonlinear equations have been developed to correlate the PV module performance in terms of electrical power output with the operating temperature. Sansui et al. carried out statistical analysis where the favorable conditions of conversion of solar energy to electricity have been shown [9]. But in the recent study, the statistical analysis has been done on correlation concept considering confidence limit of 95% for the two different ambient parameters, namely, ambient temperature and wind speed. Also as Bhilwara is a flat area, the ambient temperature differs in different seasons. The analysis has been done for twelve months period to cover seasonal effects.

Conclusion

In this paper, the effects of temperature on photovoltaic module output performance were investigated. It is seen from the result that the correlation between the efficiency and ambient temperature is very good as compared to the correlation between efficiency and wind speed. The ambient temperature has a positive correlation with the efficiency of the PV system which indicates that ambient temperature plays an important role in performance analysis. Also, there is a direct proportionality between the efficiency of the PV system and the ambient temperature of the locality. It can be concluded that the ambient temperature can be preferred for predicting the performance of photovoltaic module compared to wind speed for the present area of study. Actually when the power plants are installed at different rural areas of the state, it is seen that though the modules are placed at due south, the output power generated does not meet the desired level. This may be due to the modules manufactured at STC. Therefore, the deviation from the standard test condition affects the generation of output power. So, while designing green buildings, these ambient parameters should also be taken into consideration instead of considering only the orientation of the solar PV modules. So both mono and poly silicon solar cell influenced by

wind and solar insolation. For installation of module one should take these parameters into considerations. Mono crystalline panel have less effected by climatic change by polycrystalline.

It can be observed that the solar panel temperature is signifcantly impact by the wind velocity. The is due to wind velocity flow can be provided the cooling effect for the solar panel model surface. The highest wind velocity can be dissipated more heat generated by the solar panel to the environment. Therefore, the solar panel can generate a good performance with the lowest temperature.

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