



Impact of Cloud, Rain, Humidity, and Wind Velocity on PV Panel Performance

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Abstract

Before the invention of solar panels, solar energy had been used for millions of years. To survive and increase many forms of life, people rely on sunlight. For example, use sunlight for warmth and have only recently begun to use the sun's energy to generate renewable and sustainable electricity. The widespread use of photovoltaic PV systems as a source of renewable energy-derived electricity has prompted researchers to investigate the factors that influence their performance. This paper presents an analytical study for assessing the performance of a 120 Wp PV module. This experiment was conducted at Al-Nasiriyah city (31.03 N, 46.16E). At 180° south, and 45° elevation, the solar panel is omitted. Using solar panels, solar energy is converted into electrical energy that can power an entire building. The power production from the solar panel depends on several identified factors. In February and June, the solar panel tested the effect of cloud cover, rain, relative humidity and wind velocity. On rainy and cloudy days, average power and irradiance are reduced by 93.32 %, 93.77 %, and 79.97 %, 77.34 %, respectively, when compared to power and irradiance on a clear day (8th February) 693 W/m² and 76.55 W. Humidity has an inverse relationship with voltage, current, and power. It means that as humidity rises, the value of voltage, current, and power decreases. The performance of a solar panel is directly proportional to the wind velocity. The temperature is inversely proportional to wind velocity, i.e. as wind velocity increases, the temperature of the solar cell module decreases. The results of this study have been analyzed and discussed.

Keywords: Solar cell, efficiency, cloud cover, rain, humidity, wind velocity.

الخلاصة: قبل اختراع الألواح الشمسية ، تم استخدام الطاقة الشمسية لملايين السنين. للبقاء والازدهار ، تعتمد العديد من أشكال الحياة على ضوء الشمس. يستخدم البشر ، على سبيل المثال ، ضوء الشمس للدفع وقد بدأوا مؤخرًا في استخدام طاقة الشمس لتوليد كهرباء متجددة ومستدامة. دفع الاستخدام الواسع النطاق للأنظمة الكهروضوئية كمصدر للكهرباء المشتقة من الطاقة المتجددة الباحثين إلى التحقيق في العوامل التي تؤثر على أدائها. يقدم هذا البحث دراسة تحليلية لتقييم أداء وحدة كهروضوئية 120 واط. أجريت هذه التجربة في مدينة الناصرية (31.03 شمالاً ، 46.16 شرقاً). عند 180 درجة جنوباً ، وزاوية ميل 45 درجة. يتم تحويل الطاقة الشمسية إلى طاقة كهربائية يمكنها تشغيل مبنى بأكمله. يعتمد إنتاج الطاقة من الألواح الشمسية على عدة عوامل محددة. في فبراير ويونيو ، اختبرت اللوحة الشمسية تأثير الغطاء السحابي والمطر والرطوبة النسبية وسرعة الرياح. في الأيام الممطرة والغيوم ، ينخفض متوسط الطاقة والإشعاع بنسبة 93.32٪ و 93.77٪ و 79.97٪ و 77.34٪ على التوالي ، عند مقارنتها بالطاقة والإشعاع في يوم صاف (8 فبراير) 693 واط / متر مربع و 76.55 واط. الرطوبة لها علاقة عكسية بالجهد والتيار والطاقة ، مما يعني أنه مع ارتفاع الرطوبة ، تنخفض قيمة الجهد والتيار والطاقة. أداء الألواح الشمسية يتناسب طردياً مع سرعة الرياح. تتناسب درجة الحرارة عكسياً مع سرعة الرياح ، أي كلما زادت سرعة الرياح تنخفض درجة حرارة وحدة الخلايا الشمسية ، وقد تم تحليل نتائج هذه الدراسة ومناقشتها.

1. INTRODUCTION

In developing countries, the rate of energy consumption per capita has become a criterion of success, ensuring that the growing society has constant energy [1, 2]. Fossil fuel reserves, which supply the majority of the world's energy, are finite and, in general, diminishing as a result of environmental issues [3]. The current production-consumption energy model is unsustainable, highlighting the finite nature of conventional energy sources. The

serious environmental problems caused by current emissions generated by the use of fossil fuels include acid rain, the greenhouse effect, and ozone layer depletion, all of which are irreversible in many cases. Research is ongoing to develop a more efficient method of producing energy from alternative, environmentally friendly sources. The world is on the verge of depletion of non-renewable energy sources; oil, coal, and gases provide 80% of power, while renewable energy sources such as solar power, wind power, hydropower, and others provide only 20% [4]. Non-renewable energy sources are the primary source of pollution in the environment. solar power is the fastest-growing source of energy[5]. The efficiency of solar cells has improved in recent years as a result of the development of new methods and technologies, as has the cost of manufacturing. Despite all of the advancements, many environmental factors, such as clouds, rain, and humidity, have an impact on the performance of solar cells [6, 7].

2. LITERATURE SURVEY

A B-K Precision Model 615 Digital Light instrument was used to investigate the effect of relative humidity on the efficient conversion of solar energy to electricity using photovoltaic (PV) modules in Port Harcourt (tropical climate region). According to the findings, relative humidity has a negligible effect on the photovoltaic module's output voltage. Under operating conditions of 43°C and 77 % relative humidity, the manufacturer's maximum power of 16W was nearly achieved. A current of about 18.42×10^{-1} A was also measured, with an efficiency of about 82 %. Both current and efficiency are observed to be affected by relative humidity [8-10]. The effect of relative humidity on the output of a solar photovoltaic system was studied [11, 12]. The relative humidity has an impact on the other climate variables and is influenced by them. The results revealed that relative humidity during the test period has a significant impact on PV performance. When the relative humidity rises, the PV's current, voltage, and power output decrease. The findings suggest that PV panel efficiency is low during periods of high relative humidity. The current, voltage, power, and efficiency of solar cells are all affected by relative humidity. In comparison to the other studied parameters in Sohar city, the study confirms the high impact of RH on this degradation. The effect of raindrops on the performance of solar photovoltaic (PV) cells due to dropwise condensation or rain falling on their cover was investigated experimentally in [13, 14]. Dew forms frequently in a variety of climates, including semi-arid regions that are ideal for PV cell deployment. Droplets on the solar cell's cover can then hurt the cell's power generation and efficiency due to optical effects. The incident light was back-scattered through the droplets instead of being trapped by total internal reflection at the cover/air interface before being absorbed by the solar cell, which caused the performance degradation. The effect of cloud cover on the performance of the monocrystalline photovoltaic solar module has been investigated from June to August 2015 in Niamey [15]. Results show that the cloud cover has a great impact on photovoltaic solar performance. The effect of cloud cover is immediate with a drop in global solar irradiance and hence in power output for a short time. In July, and August 2015 the heavy cloud blocks the direct component of the solar irradiance resulting in a minimum value of daily energy. The cloud's impacts are more pronounced in August and July. Indeed, on the 7th of August 2015, the maximum power was completely below 25% of the rated power (25 W). This is due to the very high cloudy conditions that are common in August, which is the month with the highest rainfall in the Sahel.

3. THE METHODOLOGY OF THE PROPOSED WORK

Studies show that the power output of the PV module is affected by several factors. These variables should be considered important for better performance when designing a PV system. The method of recording I-V characteristics panel installed on an outdoor to natural sunlight. The panel was subjected to cloud cover, rain, humidity, and wind velocity. The analysis was conducted in real-time in February. For the experiment, Istar Solar PV module 120Wp (Mono-Crystalline silicon cell) was used. The PV module is shown in figure 1. The specifications of the module are shown in table 1. To measure the level of radiance, a solar meter was used. The infrared type thermometer (Raytek) was used to measure the PV module temperature. An ac/dc type multimeter was used for voltage and current measurements. To measure the maximum tracking of power points, a solar panel multimeter (WS400A) was used. The measurements were taken from 08:00 am to 04:00 pm daily, for the period from 1st Feb. till 28st Feb. The measurements were including Irradiance, Ambient temperature, module temperature, and the output parameters (PV power and efficiency). The data was transferred directly as an excel spreadsheet using a laptop computer connected to the solar panel multimeter (WS400A) (see Figure 2).



Figure 1: PV module 120Wp.

Table 1: Panel specifications

Type	Mono-Crystalline silicon cell
Module	IS120P
Peck power	120 Wp
I_{mp}	6.75 Amps
I_{sc}	7.30 Amps
V_{mp}	17.80 Volts
V_{oc}	22.0Volts
Dimensions	1200*670*40(+ /-2mm) -/2mm
Maximum System Voltage	1000V
Power tolerance	3%+/-
Certified	IEC EN6121561730-1-2-TFV Class II

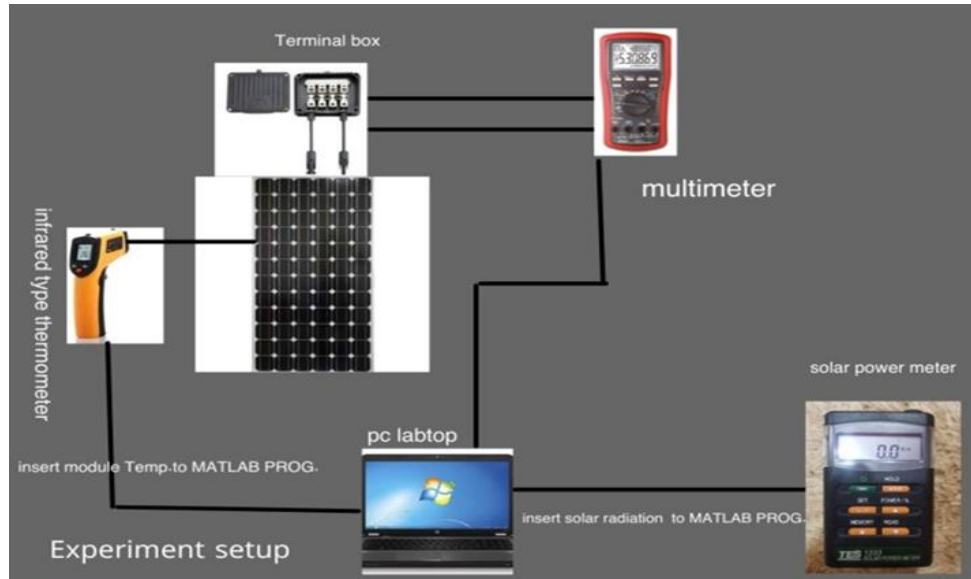


Figure 2: Experiment setup.

4. EFFECIENCY OF SOLAR CELL

The solar module efficiency (η) is the ratio between the output produced power "P" and the solar power "Polar" available on the panel surface "Ac" [16].

$$\eta = \frac{P}{P_{\text{solar}}} = \frac{V.I}{Ac.Gt} \quad (1)$$

Where V and I are voltage and current, respectively which represent the output power, Ac is the surface area of the module (m^2), and Gt is the total irradiance falling on the module surface (W/m^2).

5. FACTORS THAT AFFECT SOLAR POWER PRODUCTION

There is nothing as an ideal technological solution. The various factors that can affect the efficiency of solar panel mounting systems have been discovered through research. Rain, cloud cover, relative humidity, and wind velocity are some of the factors that have been studied to increase or decrease power production. Most solar energy is collected during midday when the sun is at its most intense, increasing power output. Rain and cloudy days reduce the amount of sunlight collected because clouds reflect some of the sun's rays, limiting the amount of sunlight absorbed by the panels.

6. RESULTS AND ANALYSIS

In this experimental analysis cloud cover, rain, humidity, and wind velocity are taken to see the effect of these factors on the power output of the PV module.

6.1 Effect of Clouds and Rain

There are two scenarios to be considered and these are a rainy day and a cloudy day respectively. The average solar irradiation and power in the first case (6th February) were about $43.11 W/m^2$ and $5.11 W$, respectively. The average solar irradiation and power in the second case (7th February) were $157 W/m^2$ and $15.33 W$, respectively. There was a large reduction in power and radiation during a cloudy day and an increase during rainy days, as shown in figures 3 and 4 when compared to power and radiation during a sunny day, as shown in figure 5. On rainy and cloudy days, average power and irradiance are reduced by 93.32 %, 93.77 %, and 79.97 %, 77.34 %, respectively, when compared to power and irradiance on a clear day (8th February) $693 W/m^2$ and $76.55 W$. Figure 6 displays real pictures of the system under raindrops and cloud cover respectively.

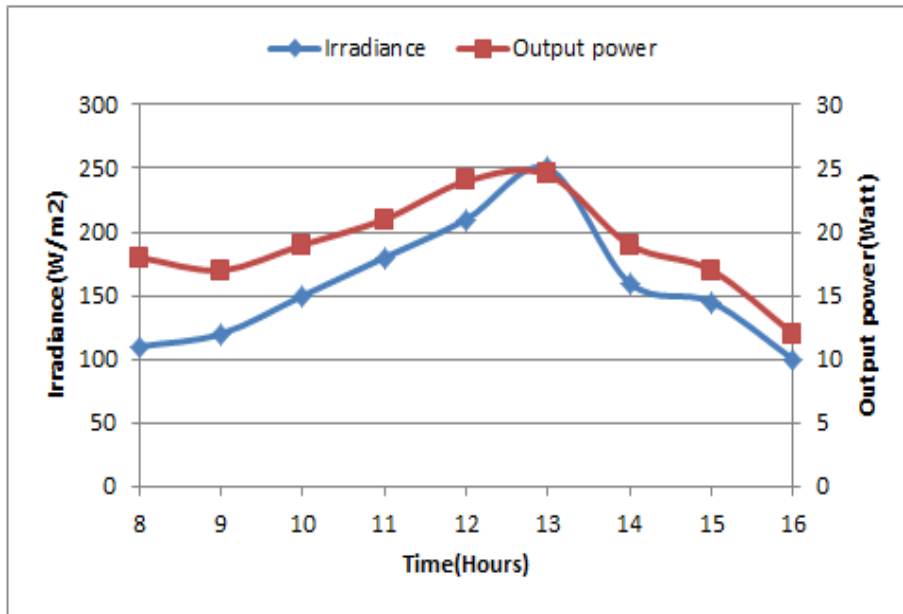


Figure 3: Power and irradiance on a cloudy day.

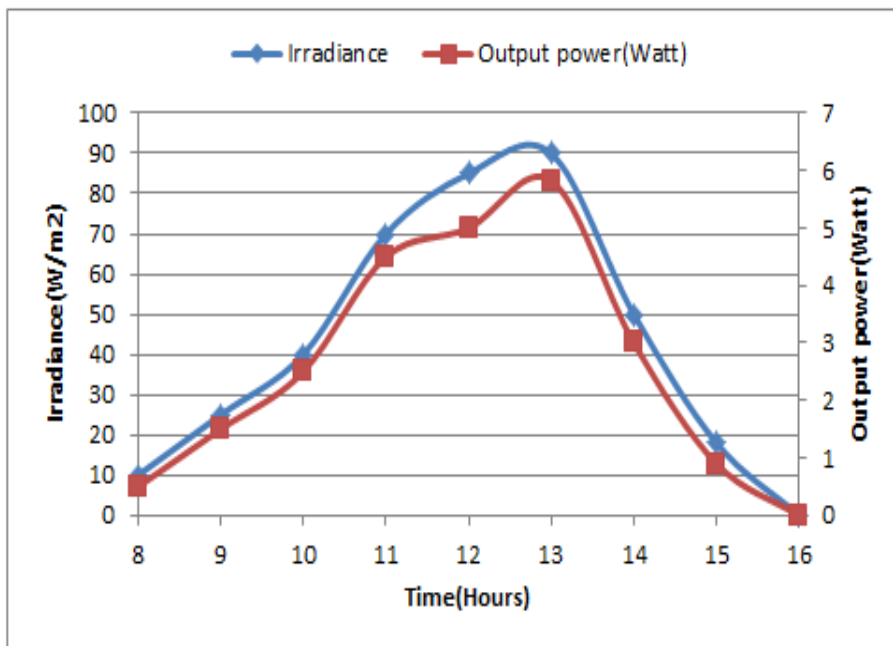


Figure 4: Power and irradiance on a rainy day.

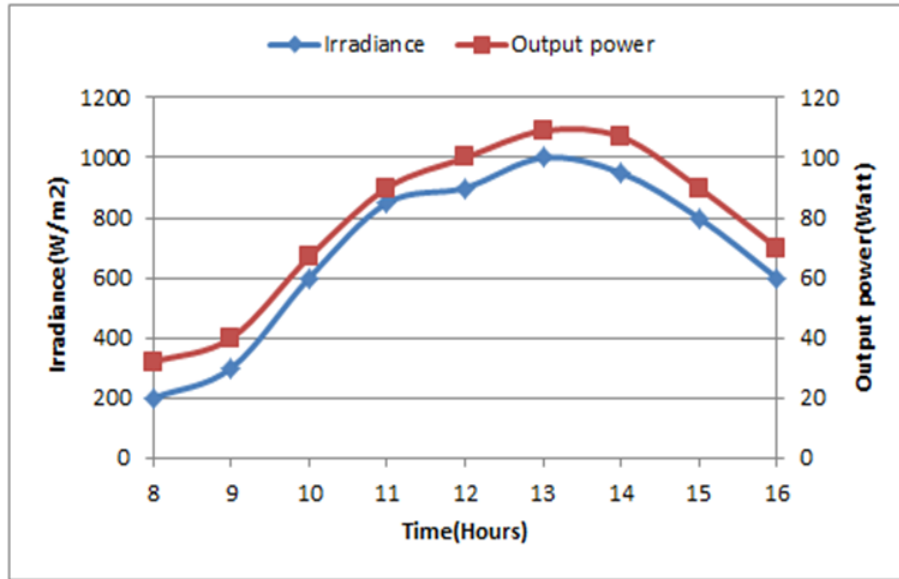


Figure 5: Power and irradiance on a sunny day.



Figure 6: (a) Module with raindrops, (b) under the influence of the clouds

From June to August 2015 in Niamey, results show that the cloud cover has a great impact on photovoltaic solar performance. Indeed, on the 7th of August 2015, the maximum power was completely below 25% of the rated power (25 W).

6.2 Effect of Humidity

Humidity refers to the amount of water vapor in the air. The humidity has two effects on the performance of solar cell modules: first, the deposition of water droplets on the surface of the solar cell module reflects the sun's light, lowering the total output of the solar cell, and second, due to the humidity the metal used in solar panel module for construction start rusting and decreases the life of solar panel [17]. Table 2 shows that humidity is directly related to voltage, current, and power based on data collected during the experiment. Humidity has an inverse relationship with voltage, current, and power, meaning that as humidity rises, the value of voltage, current, and power decreases. These relations are shown with the help of the figures below. The relative humidity in the air is

higher on rainy days. This has a minor impact on the panels; as humidity seeps into the solar panel frames, the panels' ability to produce power is reduced.

Table 2: Show data collected during the experiment (9th February).

Time (Hours)	Temperature (°C)	Humidity (%)	Voltage (DC)	Current Amp (DC)	Power (Watt)
8 am	25	25	17.1	2.78	47.5
8:30 am	25	30	16.72	2.63	43.9
9:25 am	25	35	16.53	2.42	40
10:15 am	25	40	16.45	2.3	37.6
10:50 am	25	45	16.41	2.14	35.1
11:30 am	25	50	16.33	2.04	33.3
12:45 pm	25	55	16.32	1.88	30.6

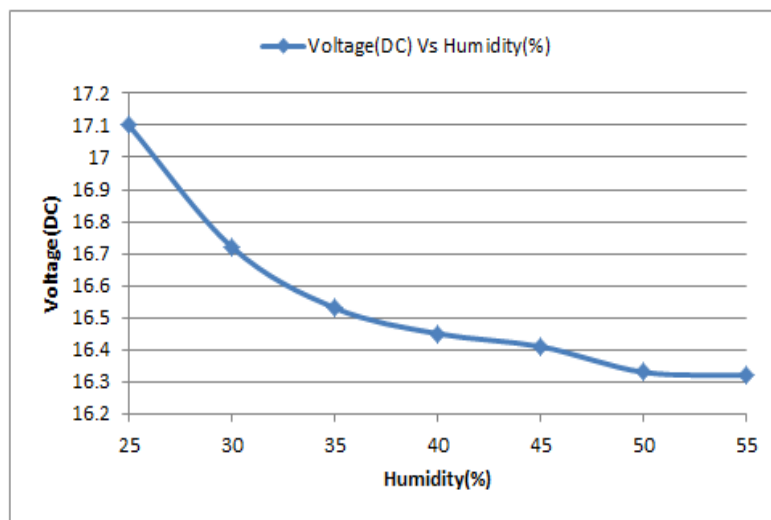


Figure 8: Humidity vs Voltage.

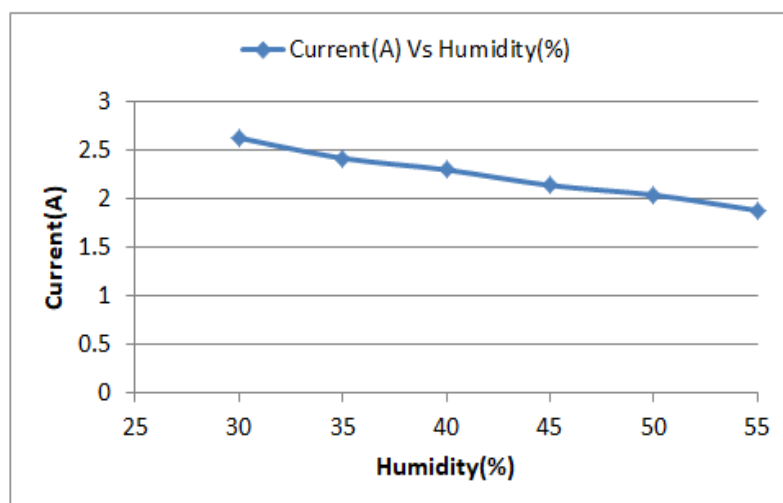


Figure 9: Humidity vs Current.

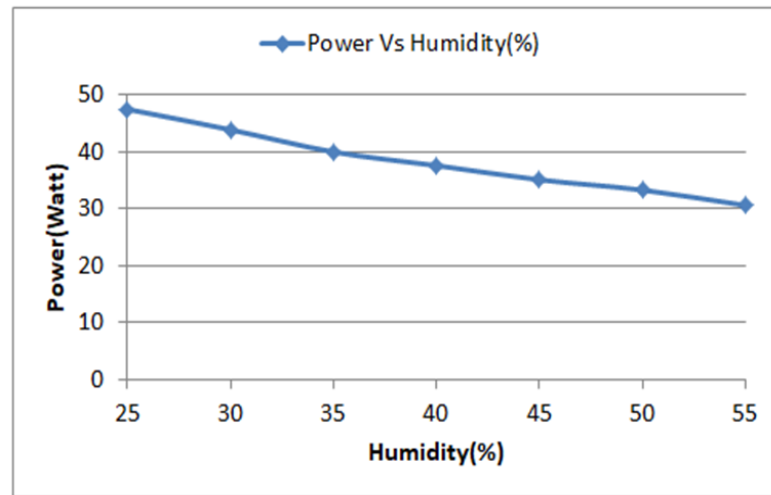


Figure 10: Humidity vs Power.

According to Kazem et al [11], relative humidity has a negligible effect on the photovoltaic module's output voltage. Under operating conditions of 43°C and 77% relative humidity, the manufacturer's maximum power of 16W was nearly achieved.

6.3 Effect Of Wind Velocity

The wind velocity has a positive effect on the performance of solar cells, increasing their efficiency. Flowing on the surface of the solar cell module helps to reduce the impact of temperature on the cell, lowering the temperature of the solar panel and affecting its performance. In other words, the performance of a solar panel is directly proportional to the wind. Temperature and wind velocity are plotted in figure 11, and as shown, the temperature is inversely proportional to wind velocity, i.e. as wind velocity increases, the temperature of the solar cell module decreases. When the average wind speed increases on some days during June, the dust has accumulated on the surface of the solar module.

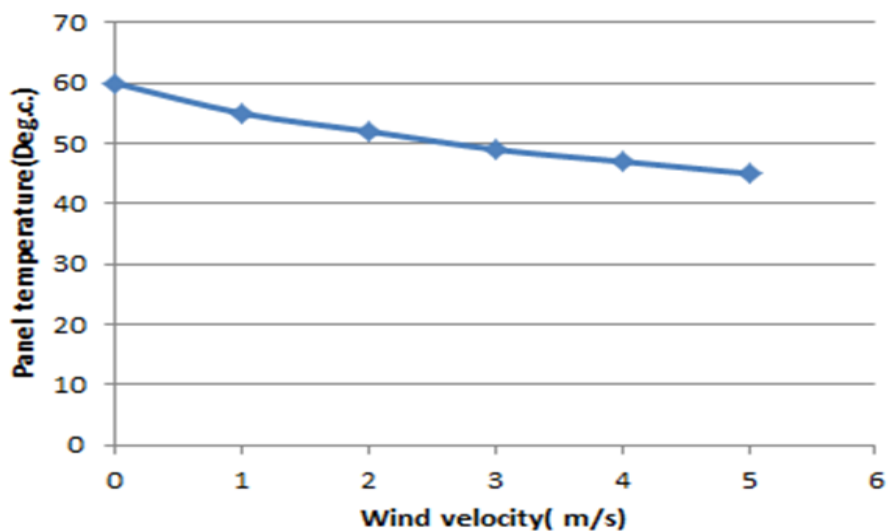


Figure 11: Temperature vs Wind Velocity in June.

7. CONCLUSION

This paper examines factors that affect the efficiency of solar cells. All identified factors, cloud cover, rain, relative humidity, and wind velocity have affected the solar power production efficiency of the solar panel

mounting. The first three factors exhibit an inverse relationship with solar power production. As the values of these factors increase the solar power production decreases. The weather has a considerable impact on the collection of dust on solar panels, which has an impact on their performance. For example, rain in some months causes the natural cleaning of PV solar panels, particularly in February. When the average wind speed increases on some days during June, the dust has accumulated on the surface of the solar module. On the other hand, the high wind speed helps to clean the solar panels naturally, reducing the amount of dust that has formed on the surface.

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