Photovoltaic cell performance analysis under different ambient temperature and wind speed for sustainable energy

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Abstract:

Environmental parameters have great impact on photovoltaic systems. It is important to understand the effect of environmental factors on photovoltaic systems. Irradiance, ambient temperature, wind speed, humidity, clouds is important environmental parameters which have direct impact on photovoltaic systems. In this work ambient temperature and wind speed are analyzed and their activities with the performance of photovoltaic cell are understood. Wind speed and ambient temperature are related to each other and together they have effects on photovoltaic systems. In this work, it is viewed that when ambient temperature is increased then the power production of the PV cell decreases. About wind speed, when the wind speed is increased then the PV power production increased is observed in this work. In total effect when ambient temperature and wind speed changes at a time what happens to PV power is discussed. Significant result is observed that is, the time wind speed is high and ambient temperature is low the PV cell power is more and on the other hand in the time when there is no wind flow and

temperature is high then the power production from PV is low. For crystalline silicon cell the maximum power point decrease linearly with the increase of ambient temperature and maximum power point increasing with increase of wind speed.

Keywords: Photovoltaic system, ambient temperature, wind speed, maximum power point

I. INTRODUCTION

People all over the world are concerned about the global warming. For making this world sustainable for future generations, people are taking different initiative to slow down the rising rate of global temperature. Photovoltaic (PV) cell is the power generation system, which does not produce any greenhouse gas in the production time. PV cell has gained much attention for its simple method of producing energy. For sustainable development, it is important to give importance to renewable energy. Among them PV has great prospect because of reduction of price very rapidly and improvement of its efficiency.

Fig. 1 shows the future state of the world CO_2 emission in different situation. It seems that when people rely on renewable energy more, the emission of CO_2 will reduce and the temperature of the world will be also decrease Ref. (1).

Establishing sustainable development needs more concern about renewable energy production, among all of them PV power production shows significant results Ref. (2). More growth of PV systems will make better environmental condition for future. It helps to reduce global warming. Climate change can be mitigated by using more renewable energy and it identified that PV system has great prospect to produce energy for green civilization. To make sustainable system PV is important because it has low carbon footprint Refs. (1, 2).

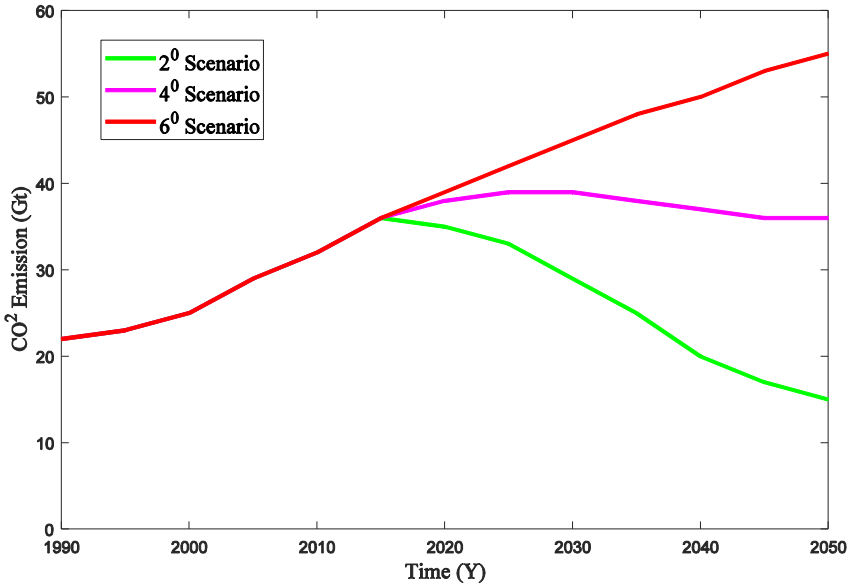

Figure 1. Future state of the world CO_2 emission.

Understanding the environmental effect on PV cells is important to design a PV plant in a certain geographical area. It is possible to analyze the PV plant output before making a PV cell plant in specific area. To do this work, the environmental parameters and the PV cell datasheet are enough to calculate the future output from the system Refs. (2, 3). But things should be analyzed clearly and carefully.

In section II, discuss about the relation between PV and sustainable development. In section III, basic about photovoltaic cell is discussed and methods of the work is discussed. In section IV, the simulation and result is given. In section V, discussion about the outcome of the simulation is discussed. In section VI, the conclusion of this work is written.

II. SUSTAINABLE DEVELOPMENT

There are three pillars for sustainable development, such as economic development, social development and environmental protection Ref. (3).These three pillars are interdependent and in

the long way they cannot exist without others. With the growth of human civilization, the power consumption is increasing radically. More the society becomes modernized more it needs power. Power has very deep relation with the growth of human civilization. More use of power is threatening to environment because of the negative impacts of the sources used in the production of power energy. They produce greenhouse gases emissions Ref. (2, 3).

The sustainability means the economy, society and environment and all of them are interconnected. It is important to develop the world but also very important to keep the environment safe.

Renewable energy is the hope for making sustainable development. PV is one important parts of renewable energy. Last few years PV got the most attention among different types of renewable energy because of its increased energy security, mitigation of climate change, sustainable development and on the other hand social benefits like generating new source of employment, reduction of air pollution which helps to improve the health condition Ref. (3). For making sustainable development which is directly related to energy development could be done by using of PV. PV plant could be made centrally and at the same time it could be installed on the rooftop of house. Using rooftop PV plant one can be benefited in two ways, producing electricity for own and can sell extra electricity to central power grid Ref. (4).

III. MODELING

A. Photovoltaic Cell

PV cell is a simple electrical device which converts solar energy into electric energy based on the basic physics law of photo-effect. Light fall on the semiconductor surface and when the

lights have enough amount of energy to move one electron from its bound shell then it becomes free electron and generates a hole. Free electron and hole are the main part for generating electrical power through the arrangement Refs. (5-8).

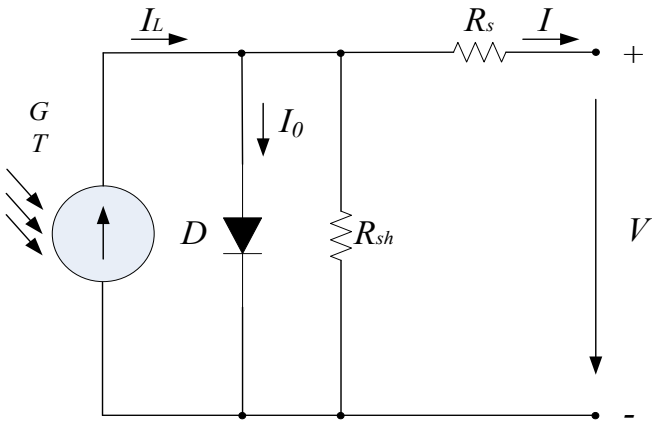

Figure 2. Single diode PV cell model.

PV cell is represented by Shockley diode equation which represents by Fig. 2. In Fig. 2, have different component which represent the internal behavior of basic PV cell Refs. (9-12). This behavior is explained by the Shockley diode equation given by

$$I = I_L - I_0 \left[\exp\left(\frac{e(V+IR_s)}{nkT}\right) - 1\right] - \frac{V+IR_s}{R_{sh}} \quad (1)$$

In (1), the main parameters are total current, irradiation, internal temperature, shunt resistance, series resistance, ideality factor, diode saturation current and load Refs. (13-17).

There are two types of temperature what are associated with PV cell output, one is environmental temperature and another is PV cell internal temperature Refs. (17-19). Cell temperature is directly associated with the PV cell basic equation. Cell temperature is directly related with ambient temperature Refs. (20-26).

B. Methods

This work is to analysis the ambient temperature and wind speed effect on the PV cell. Here the tilt angle is not taken into the account. Only the equations are used to identify the effect on PV cell Ref. (21) given by

$$T_{cell} = T_{air} + 0.035\,G \tag{2}$$

Firstly (2) is used to calculate the internal cell temperature using the ambient temperature Ref. (21). Ambient temperature is varied in a range and for each of the temperature the internal cell temperature is calculated using (2) and recorded. Then using those temperatures, the PV cell characteristics are drawn using the I-V and P-V curve. Wind speed and ambient temperature effect on cell temperature is calculated, given by

$$T_{cell} = T_{air} + \frac{0.32}{8.91+(2\times V_{wind})}\,G \tag{3}$$

To observe the wind speed effect on cell temperature, different wind speed is taken from a valid range (0 m/s^2 to 11 m/s^2) and using the wind speed with different ambient temperature, the internal temperature is calculated using (3) Ref. (22). After calculating internal then the values are used for drawing the curve for I-V and P-V curve. In total process, the irradiance is kept fixed at standard irradiance value of the 1000 W/m^2. Analysis with irradiance was done before Refs. (20, 21).

At the end, both ambient temperature and wind speed are varied in the same time to get the effect on PV cell. Maximum power point for each of the event is recorded. A three dimensional plot is drawn using maximum power point, and speed and ambient temperature values. Then one plot is making using the maximum power points at different ambient temperature and another plot is making with the maximum power point at different wind speed.

IV. SIMULATION

The mathematical modeling for the crystalline silicon (c-Si) PV cell considering two environmental parameters are implemented in Matlab to get the clear view of their effect on PV. Table 1 consists of the data about c-Si which is used for the simulation work. Ambient temperature (273K to 328K) and wind speed 0 m/s^2 to 11 m/s^2 are used to conduct the simulation.

Table 1. Data for the c-Si solar cell at STC

Technology	V_m^*	I_m^*	V_{oc}^*	I_{sc}^*	α_{sc}
c-Si	0.55 V	1.98 A	0.64 V	2.1 A	1.7 mA/ºC

Following the method, different important findings have been achieved about the PV cell characteristics when the ambient temperature and wind speed are changed.

Fig. 3 shows that when the ambient temperature is increasing then the output current is increasing and on the other side the voltage is decreasing.

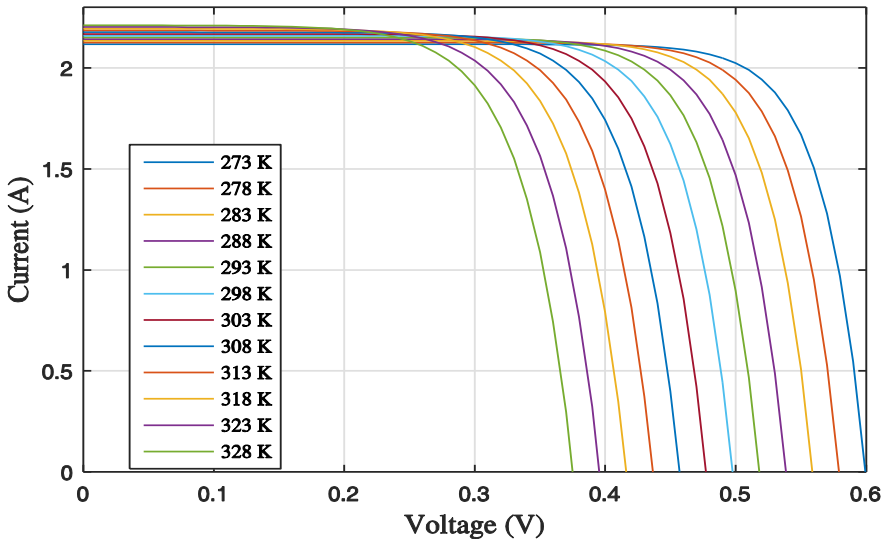

Figure 3. I-V curve under different ambient temperature.

Fig. 4 shows that the power is decreasing when the ambient temperature is increased.

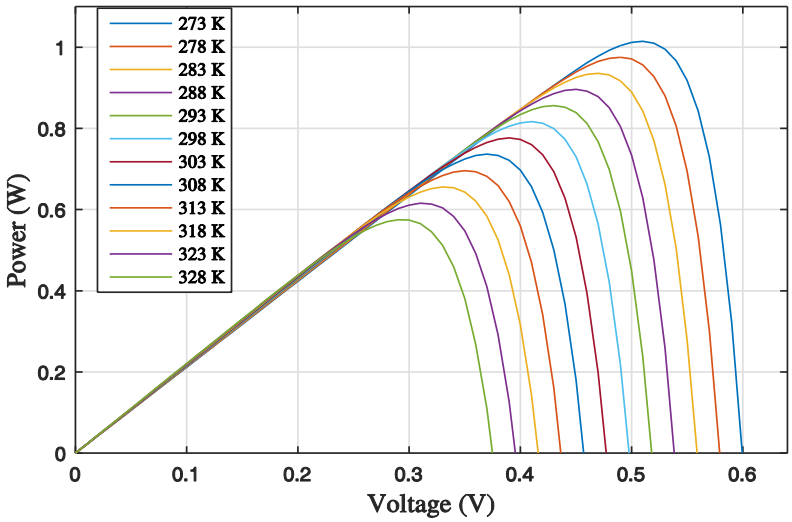

Figure 4. P-V curve under different ambient temperature.

Fig. 5 shows that the wind speed is increasing when the output current is decreasing and on the other side the voltage is increasing.

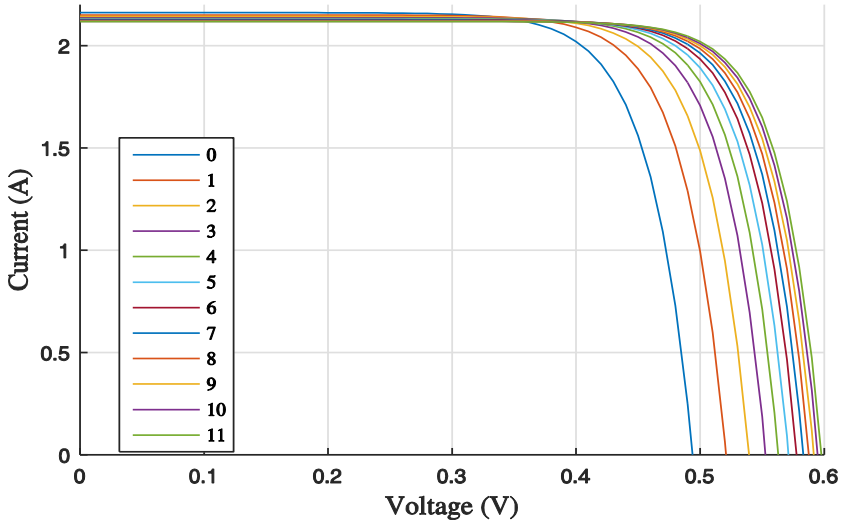

Figure 5. I-V curve under different wind speed.

Fig. 6 shows the maximum power point is increasing when the wind speed is increasing. This shows the positive effect on PV cell.

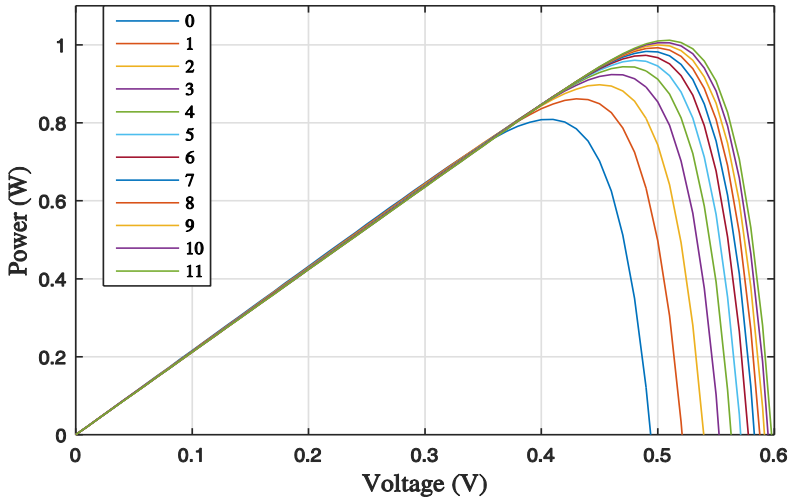

Figure 6. P-V Curve under different wind speed.

Then a work has been done to see the effect of changing ambient temperature with wind speed and track the maximum power point of PV. The outcome of the work is shows in Fig. 7.

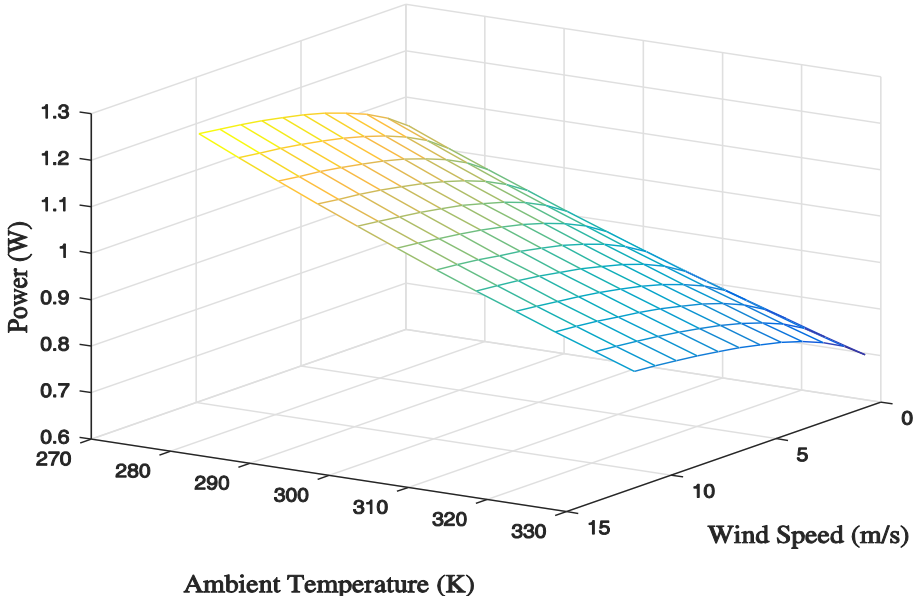

Figure 7. Maximum power point of PV with ambient temperature and wind speed changings.

From Fig. 7, the maximum power point is values are stored in changing of these two environmental parameters. It clearly shows what is happening with both changing variable. Low ambient temperature and high wind speed will increase power of PV cell.

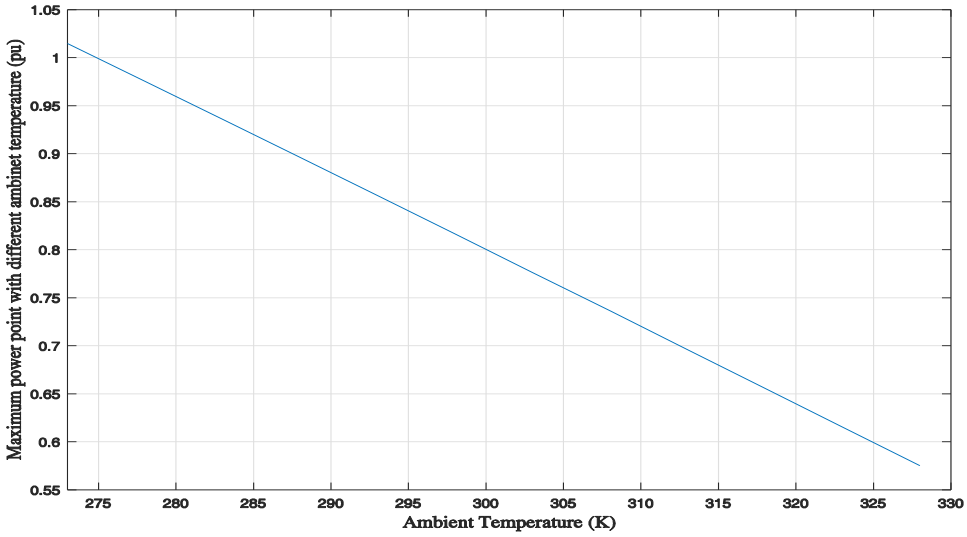

Figure 8. Maximum power point varies with different ambient temperature.

Fig. 8 shows that when ambient temperature is increasing the maximum power generation from the PV is decreasing and it's happed linearly. Ambient temperature has negative impact on PV. It is important to keep the ambient temperature low and have to implement different techniques to reduce it.

Fig. 9 shows the result of impact of wind speed on PV maximum power generation. It is very rational when the strong wind blow near the PV modules, it takes away the hot air near the PV and its help it to keep the ambient temperature low and help to cool the PV cell.

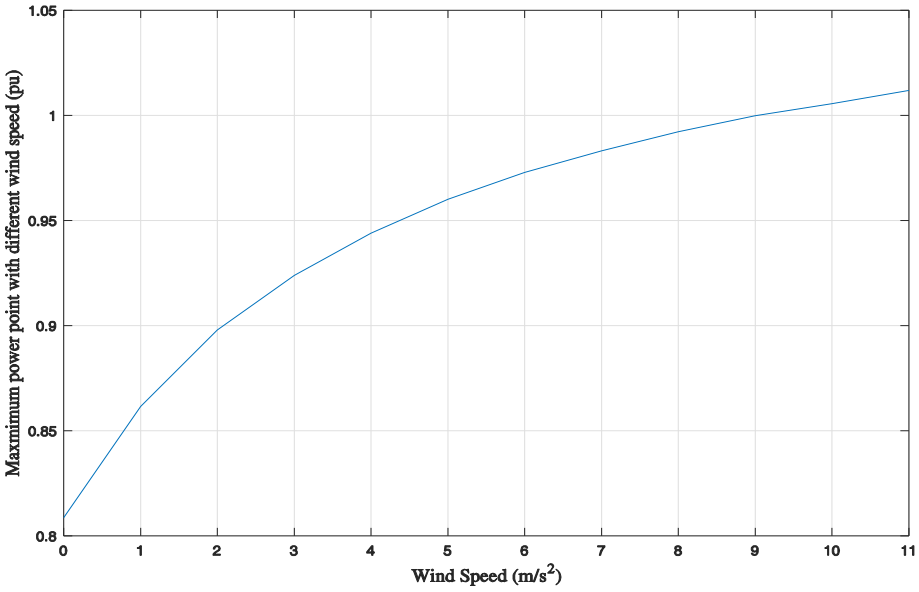

Figure 9. Maximum power point varies with different wind speed.

V. DISCUSSION

From Fig. 3 and Fig. 4, it is showed that when the ambient temperature is increased then the current also increased a little but on the other hand the voltage decreased. In the total effect the maximum power point decreased when the ambient temperature is increased.

From Fig. 5 and Fig. 6, when the wind speed is increasing the current is decreasing and on the other hand the voltage is increasing. In maximum power point the value is increasing when there is more wind speed.

Fig. 7 shows the maximum power when the wind speed and ambient temperature are varied. Low ambient temperature with high wind speed give the maximum power and high temperature with low wind speed gives very low measure of maximum power point.

Fig. 8 gives that when ambient temperature is changing then the maximum power point of c-Si is decreasing linearly and Fig. 9 gives that when wind speed is changing then maximum power point of c-Si cell is increasing.

VI. CONCLUSION

In this simulation, the tilt angle of PV cell is not included; this angle may have great impact on these variables. This point will be included in next simulation to identify its effect. From this work it was proven that for getting maximum power the ambient temperature should be low and wind speed should be high. Taking these parameters into account, people could select place where the PV plant could be built. For sustainable development PV have great importance. More installation of PV plant will reduce the carbon footprint.

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