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Effect of Temperature on PV Performance Based on Experimental Study

Khaleel I Abass
Mechanical Engineering Department, University of Technology, Baghdad, Iraq

Abstract- Solar energy is clearly available and very large in Iraq, which is clean energy, friendly to the environment and can be used to produce clean electricity in a country that has been suffering for decades from a lack of electricity supplies in addition to a large pollution in the environment. In this study, the effect of weather conditions, especially solar radiation, and the temperature of the photovoltaic unit, as well as the air temperature on the photovoltaic cell outputs installed at the University of Technology, east of Baghdad, were evaluated. The results proved that the high intensity of solar radiation helps increase the electricity generated, but at the same time it causes a high increase in the temperature of the PV unit, which causes a decrease in its productivity. High ambient air temperature limits the process of cooling the solar panel and, as a result, the performance decreases. The study concluded that the use of photovoltaic/thermal PV systems (PVT) solves the dilemma of low performance of photovoltaics due to the high intensity of solar radiation and the temperature of the air that characterizes the Iraqi city of Baghdad.

Keywords: *PV Module, Climatic Conditions, Radiation Intensity, Baghdad-Iraq*

I. INTRODUCTION

The environment forms everything that surrounds us from living creatures and non-living materials that have a direct impact on human life. They are water, air, rocks, and soil, in addition to living organisms, and all of this system comes together to enable a person to live on earth comfortably [1]. The environment is not only for humans, but humans are the most influential people in the environment. When we consider the pollution problems that our planet suffers from, we realize that the influence of humans is not always positive [2]. Among the most important environmental problems that the planet suffers from today are the following:

Air pollution: The World Health Organization (2016) report indicates that (92%) of the world's population lives in places with polluted air, and that every year three million deaths occur due to air pollution [3]. Air pollution is mainly caused by smoke from burning fossil fuels to produce electrical energy or in melting furnaces, as it is burned in cars, ships, planes, etc. [4, 5]. The burning of this fuel results in sulfur oxides, volatile organic compounds, radon, and other pollutants whose concentrations cause great health risks to humans, animals, and plants [6, 7].

Water pollution: means pollution of streams, rivers and oceans resulting from acid rain, oil spills, sewage, and runoff in urban areas [8].

Global warming: greenhouse gases lead to global warming, which raises the temperatures of the Earth's surface and oceans, which in turn leads to melting of the polar ice cap, sea level rise, and the resulting heavy snowfall, floods, and desertification also [9]. NASA reports indicate that the Antarctic ice sheet is declining by 13% per decade, and that sea level has increased by 7 inches during the past hundred years [10].

Climate change: the proliferation of factories and the burning of fossil fuels lead to the production of gases that increase the temperature of the atmosphere, lead to global warming, changing weather conditions, accompanied by melting of polar ice, the occurrence of floods, the spread of new diseases, and change in seasons [11].

Soil problems: including soil degradation as a result of many factors, including: agricultural processes, overgrazing, logging, and deforestation. Soil degradation leads to the phenomenon of desertification, and other problems that it suffers from are: soil, salinization of soils, and soil contamination with heavy metals, and pesticides pests and waste [12].

Pollution of drinking water: One of the environmental problems that raises fears for many people is pollution of fresh water intended for domestic needs, including drinking water, and fresh water can be polluted in rivers, lakes, and even reservoirs with micro-organisms, disinfectants, organic and inorganic compounds, and radioactive elements [13].

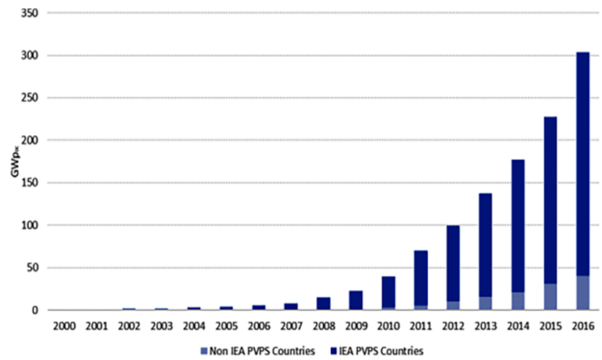

Fig. 1: The evolution of PV panels installations (GWPDC) between 2000 and 2016 as per the annual reports of the International Energy Agency in 2016 [34].

The researchers and the decision makers agreed that the best treatment for the above environmental problems is by heading towards renewable energies such as solar energy, wind energy, etc. These energies are environmentally friendly, do not emit harmful pollutants and do not increase global warming [14]. Among the most important renewable energies is solar energy, which can be considered the origin of all energies. This energy has been used since thousands of years for pre-heating, material heating and treatment. Today, this energy has many applications that can be used as a thermal energy, which can be used to ventilate and heat spaces using the Trombe Walls [15-19]. It can also be used to heat a saline water basin and to take advantage of the heat stored in many applications [20-22]. The thermal energy in the sun's rays is the fuel of solar air heaters, and it has proven its efficiency and capabilities in many different locations and is now practically applied in many countries [23-25]. It is also possible to produce electrical energy from the heat of solar radiation using concentrated solar power stations that have spread around the world with high efficiency [26-30]. Electricity can also be produced directly from the sun's rays using photovoltaic cells, which during the past decade has increased the number of units and energy produced by this application to record levels [30, 33]. Figure 1 shows the rise in electricity produced globally by using PV modules [34].

Today, hydrogen production is being studied using the sun's heat or solar electricity to break up the water and then take advantage of this hydrogen as a fuel to run fuel cells that have become a common application because of its efficiency and because it does not produce exhaust pollutants other than water and some heat [35].

Although solar systems have good efficiency and produce adequate heat or electricity, their disadvantage is being affected by weather conditions such as the ambient temperature [36, 37], intensity of solar radiation [38, 39], relative humidity [40, 41], clouds [42, 43], shadow [44, 45], and dust [46, 47]. These factors reduce the productivity of solar applications, which is the reason why they are not widespread today, especially in countries that suffer from an unusual rise in these conditions.

Photovoltaic cells, which are the most important solar applications today, give the best electrical efficiency at low photovoltaic temperatures, depending on the material made of them. All the types of photovoltaic cells decrease their efficiency and performance by increasing their temperature. Most of the solar radiation falling on the photovoltaic plate is absorbed as heat, and a small portion of this radiation is converted into electricity. So the researchers tended to find ways to reduce the temperature of the solar units to increase their performance [48].

In this study, the effect of solar radiation intensity and solar panel temperature on the cell's electrical performance will be practically determined. Weather conditions differ from one region to another and from one semester to another, so the study area must be determined. The study area is Baghdad, the capital of Iraq, which is located on the Tigris River and is characterized by a very hot summer and a short and cold winter. The intensity of the solar radiation of this city is high and the duration of the sun’s brightness is long, which makes the use of photovoltaics appropriate for generating electricity in a country that suffers from a severe shortage of electricity supplies for more than two decades [49].

II. EXPERIMENTAL SETUP

A. PV module

A photoelectric cell (Table 1) was used and placed facing south and at tilt angle of 30° from the horizon to suit the Baghdad sun.

Table 1: specification of PV panel

Specification of PV panel	Value
Voltage open circuit Voc	19.7 V
Current short circuit Isc	1.08 A
Peak voltage	19.13 V
Peak current	2.00 A
Maximum	

B. Characteristic equation of PV

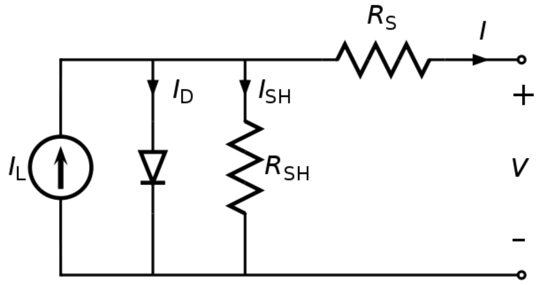

Fig.2 circuit of PV system

For the electrical circuit shown in Fig. 2, and by applying the KCL low, the node of the model reported in the figure, there are some equations. From the equivalent circuit it is evident that the current produced by the solar cell is equal to that produced by the current source, minus that which flows through the diode, minus that which flows through the shunt resistor:

$$I = I_L - I_D - I_{SH} \quad \text{…………….. (1)}$$

Where

- I = output current
- I_L = photo generated current
- I_D = diode current
- I_{SH} = shunt current

The current through these elements is governed by the voltage across them so:

$$V_D = V + IR_S \text{…………….. (2)}$$

Where

- V_j = voltage across both diode and resistor R_{SH}
- V = voltage across the output terminals
- R_S = series resistance

By the Shockley diode equation is explain the current circulating through the diode is:

$$I_D = I_o \left\{ e^{\left(\frac{qV_i}{nKT}\right)} - 1 \right\} \text{…………….. (3)}$$

By substituting the equation of Vi (2) in (3) then the current diverted through the diode is became:

$$I_D = I_o \left\{ e^{\left(\frac{q(V+IR_S)}{nKT}\right)} - 1 \right\} \text{…………….. (4)}$$

Where

- I_0 = reverse saturation current
- n = diode idealist factor (1 for an ideal diode)
- q = elementary charge1.6x10-19 Coulombs
- k = Boltzmann's constant 1.38×10^{-23} J/K
- T = absolute temperature
- At 25°C, the $\frac{KT}{q} \approx 0.0259\ volt.$

By Ohm's law, the current diverted through the shunt resistor is:

$$I_{SH} = \frac{V_D}{R_{SH}} \text{…………….. (5)}$$

Where

- R_{SH} = shunt resistance.

Than by substituting the equation of V_D (2) in (5) then we get:

$$I_{SH} = \frac{V + IR_s}{R_{SH}} \quad \text{…………….. (6)}$$

After that we substitute the equation of the temperature to use it whenever we want to see the effect of temperature on the pv performance.

$$I_L(t) = I_L\left(1 + TIPH\ (T - T_{mean}\ )\right) \ldots\ldots\ldots\ldots\ldots\ldots(6)$$

Where

- TIPH is the First order temperature coefficient for IL.
- T_{meas} is the Parameter extraction temperature.

Substituting these all currents into the first equation which is presenting the characteristic equation of a solar cell, which relates solar cell parameters to the output current and voltage:

$$I = I_L\left(1 + TIPH\ (T - T_{mean})\right) - I_o\left\{e^{\left(\frac{q(V+IR_S)}{nKT}\right)} - 1\right\} - \frac{V+IR_S}{R_{SH}} \ldots (7)$$

An alternative derivation produces an equation similar in appearance, but with V on the left-hand side. The two alternatives are identities; that is, they yield precisely the same results.

III. RESULTS AND DISCUSSIONS

Table 2: The average measurements for one month in Baghdad City

Time	PV voltage	Temperature			Load
		Ambient	Frame	Cell	
5:30	10.612	33.2	32.1	32.0	0.6A
5:51	11.616	32.9	32.4	32.0	0.6A
6:33	11.917	32.7	33.4	33.3	0.6A
6:58	11.864	33.4	35.5	36.1	0.6A
7:15	11.915	33.6	36.2	36.9	0.6A
7:45	11.967	34.2	39.5	38.5	0.6A
8:56	12.060	34.3	37.8	42.6	0.6A
9:17	12.069	34.7	39.9	40.2	0.6A
9:45	12.22	33.0	39.1	40.8	0.6A
10:15	12.53	32.3	48.1	41.2	0.6A
12:44	13.501V	47	60.5	62.4	0.6A
1:15	12.823V	42	63.1	55.3	0.6A
2:25	11.851V	38.9	66.8	48.3	0.6A
3:00	11.674V	40	64.3	49.4	0.6A
3:30	12.172V	45.7	52.2	45.7	0.6A
4:12	11.736	34.9	47.7	36.4	0.6A
4.:50	11.841	32.3	39.5	44.6	0.6A
5:20	11.693	32.2	33.6	45.1	0.6A

Table 2 shows the results of the average climatic condition for city of Baghdad at May 2019. The results indicated relatively high solar radiation close to the red belt countries radiation in intensities. The wind speed for the study period was low to moderate, which is in general represents the wind velocity all over the year in Baghdad city. The relative humidity is moderate in Baghdad climate, which means longer lifetime for the PV cells and From practical result, it is clear that there are many factor effects of temperature on the performance of photovoltaic which are ambient (25°C).Table 2 shows measuring temperature is by taken different reading in different interval of time. The ambient temperature, frame temperature and cell were recorded.

Fig. 3 shows the relationship between the time and wind speed, increasing wind speed cool down the PV panel temperature for a certain limit, especially at moderate speeds less than 5 m/s. However, the wind speed in Baghdad is low most the time and less than 2 m/s, which makes its effects limited.

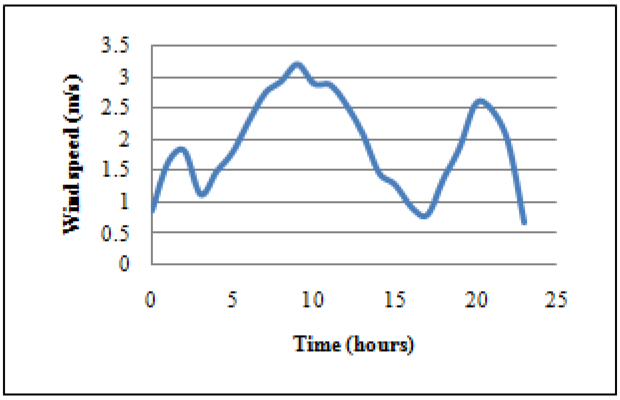

Fig. 3: The relationship between time & wind speed

Fig. 4 shows the relationship between time and solar radiation intensity. In the night, no solar radiation exists, so the result comes zero at night. Then the solar start increase with the sun shine that effect from morning until afternoon at 15 PM. The solar radiation was high reached to 800W/m^2 then decrease until reached to zero at night. Baghdad has high solar radiation intensity and at least more than six hours of shining period, these values makes Baghdad very suitable area for solar energy applications.

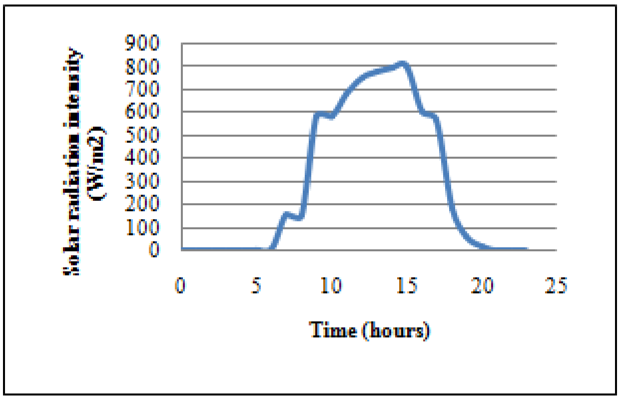

Fig. 4: The relationship between time and solar radiation

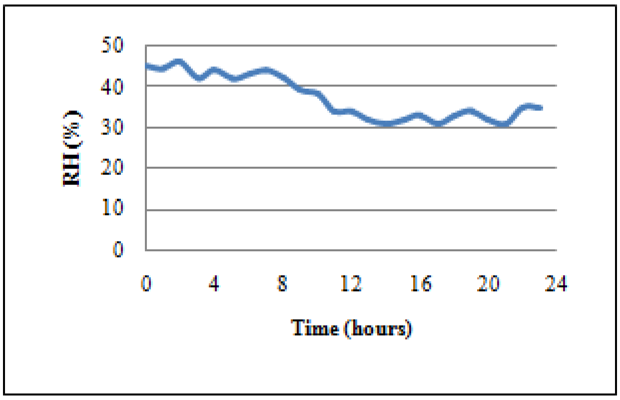

Fig. 5: Relative humidity vs. time

Fig. 5 shows the average relative humidity for the studied period. RH works in two directions as Ref. [40] indicated. The first: it has a cooling effect on the PV panel, which is a positive influence. The second: the humidity can penetrates the PV panel and corrode the wirings and defect it and reduces its lifetime. Also, especially at first daylights forms dew droplets, which can mix with dust particles and form a solid frame on the PV panel surface after it evaporates. The RH in Baghdadi weathers increases at night and reduces at midday. The recorded RH values were moderate and can affect the PV panel in a positive way as mentioned above.

Table 3 lists the measurements done on the PV panel in Baghdad climatic conditions.

Table 3: measurement obtained with instruments

Time	PV voltage	Temperature			Load
		Ambient	Frame	Cell	
5:30	10.612	33.2	32.1	32.0	0.6A
5:51	11.616	32.9	32.4	32.0	0.6A
6:33	11.917	32.7	33.4	33.3	0.6A
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4.:50	11.841	32.3	39.5	44.6	0.6A
5:20	11.693	32.2	33.6	45.1	0.6A

The results illustrated in Table 3 can be summarized and clarified in figures. Fig. 6 shows the ambient temperature and PV panel variation with time. Although the readings were taken in May but the ambient temperature measurements especially at noon were high. The high ambient temperature affects the solar module temperature as it reduces the heat transfer from the panel to surrounding or may be worse it transfersheat to the panel and increase its temperature. Increasing PV module temperature means reducing its performance.

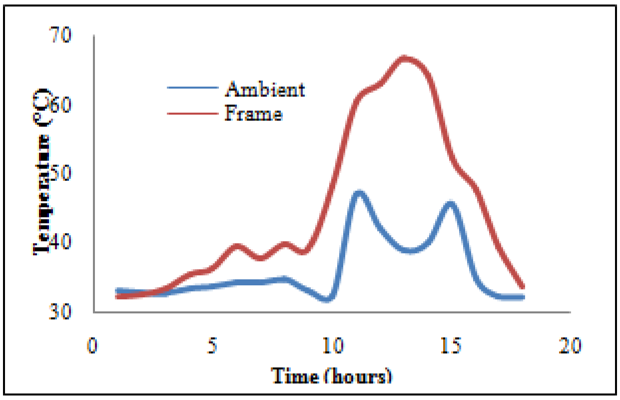

Fig. 6: The measured ambient and PV panel's measured temperatures

The relationship between PV panel frame temperature and time is shown in figure 6. It is give direct idea about what is the effect of high solar radiation on the PV panel temperature. It's also started from the low temperature because the sun just started to rise. With the time advance, the solar radiation intensity increases and a large part of this intensity converts to heat in the PV panel absorbed and resulted in high panel's temperature. As the ambient air is high then its cooling effect is reduced and heat transfer rate reduced.

Fig. 7 represents the yield of the PV panel through working period. The PV module starts generating useful power at 8 AM and on and reaches its peak at noon from 12 to 2 PM. However, due to high panel's temperatures at these hours, the generated power is less than the designed power. It is very important to reduce the panel's temperature at this period and it is preferable to use PVT systems instead of PV systems in Baghdad City.

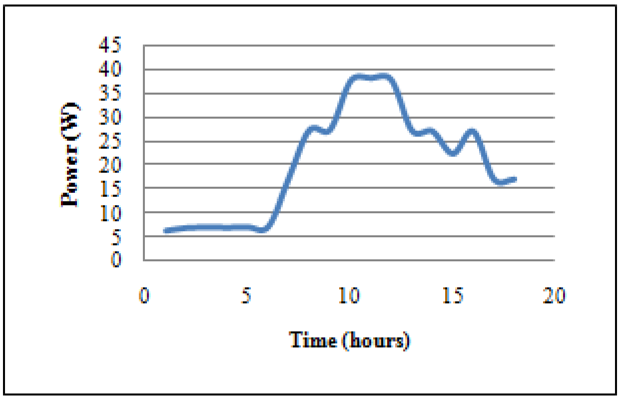

Fig. 7: Average generated power during test period

CONCLUSION

Baghdad City has high thermal radiation intensity, which makes its one of the best areas in the world for using solar energy applications. In this study, the climatic conditions of this city were measured and a PV panel performance was evaluated at these conditions. Moderate RH and low wind speeds characterized the measuring weather period. The solar radiation at this period was high and the shining period was above 6 hours. Temperature plays an important role that affects the performance of a Photovoltaic (PV) system. The study results clarified that the high solar intensity with the high ambient conditions caused high panel's temperatures. These high temperatures resulted in degradation of the outcomes power. It is much more appreciated if the authorities in Iraq encourage the use of PVT systems instead of PV systems.

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