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Effect of Solar Radiation on Photovoltaic Cell

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ABSTRACT

Solar energy applications have become one of the most promising alternatives to electricity production. Solar cells are also being used to equip many isolated consumers in areas far from the central grid around the world. In this experimental work, the effect of solar radiation on solar cell output such as voltage, current, and efficiency of a solar panels was investigated in the conditions of the city of Baghdad, Iraq climates. The data has been recorded using calibration devices. An analysis of the relationship between the intensity of solar radiation and the cell output was performed for voltage and efficiency. The results of the study show that the relationship between the intensity of solar radiation and cell output is a direct and very important relationship if not the most important among all the atmospheric variables. That increasing the intensity of solar radiation caused an increase in current output which means greater cell efficiency.

Introduction

Iraq suffers from problems in the lack of supply of electricity to citizens and factories due to increased demand for electricity in return for a severe shortage of electricity production [1]. Many citizens have resorted to the use of private or joint generators that operate on the fossil diesel and gasoline fuels, compounding environmental pollution in the country [2]. If added to this suffering, the pollution caused by the increase in the number of vehicles and trucks operating on roads, we find a great dilemma that needs quick and accurate solutions [3]-[4]. If we add to this suffering, the fluctuation in the oil markets (Iraq is one of the most important producers and exporters of this material), this caused a great pressure on the state to maintain an acceptable level of public income and the possibility of national investment [5]. Perhaps the trend to use solar energy in the production of electricity will be the fastest and optimal solution in these circumstances, especially if we consider the specifications of solar radiation in Iraq [6].

Solar energy is part of the sun's energy which falls at the earth's surface. This energy is available for many applications, such as increasing water's temperature [7], or moving electrons in a photovoltaic cell [8]. Moreover, it supplies energy to natural processes like photosynthesis [9]. Solar energy is a clean and available source on the earth throughout the year. Such clean energy is very important to the world, especially at the time of high fossil fuel costs and the critical situation of the atmosphere resulting from fossil fuel applications [10]. The solar energy data provides information on how much is the sun potential at a location on the earth's during a specific time period. These data are very important for designing and sizing solar energy systems [11]-[12]. Due to the high cost and installation difficulties in solar measurement, the solar energy data are not always available. Therefore, there is a demand to develop alternative ways of predicting the solar energy data [13].

The total global radiation at the Earth's surface consists of both short and long wave radiation [14].

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Shortwave radiation may be absorbed by terrestrial bodies and cloud cover and re-emitted as long wave radiation [15]. The shortwave radiation reaching the surface of the Earth may be direct, diffuse or reflected [16]. Direct solar radiation reaches the Earth's atmosphere as part of the solar wavelength package, which has not interacted with the particles and the ozone layer in the atmosphere. Part of this radiation is dispersed and spread out of this package due to atmospheric gases (Riley dispersion) and aerosol, which includes many substances such as pollen, soot from burning fossil fuels, suspended and rising dust particles, sulfate particles, sea salt molecules [17]. A portion of the radiation reaching the atmosphere is also reflected by the different terrain of the Earth [18]. Direct short wavelength radiation is the most important part of the Earth's radiation beam, contributing to the greatest balance of energy [19].

Photovoltaic cells (PV) as their name indicates, the photo means "light" and voltaic means voltages, which means "electricity". These cells convert sunlight directly into electricity [20]. Photovoltaic cells directly transform the light into electricity at the atomic level [21]. Solar cells are made of semiconductor materials with a property known as the photoelectric effect. These materials when they absorb light photons, release electrons known as the free electrons [22]. When these free electrons pass between two poles produce an electric current that can be used [23]-[24]. Photovoltaic can be used in many applications fields as in Agriculture, where it is used in water-pumping installations. This application is very important in developing Countries that provide it with automatic irrigation systems [25]-[26]. Also, it can be used in Industry [27], Telecommunications [28], and Public Services [29]-[30]. It is now used in Cathode protection of gas, oil pipelines and other types of piping [31]. Solar cell systems generally provide energy and reduce limited electrical charges (within a few kilowatts). It also supplies electricity always in areas far from the grid or where it cannot rely on energy (intermittent power supply) [32].

Photovoltaic are used in Health sector from decades especially for electricity generation in remote areas for refrigeration. This application is very important and useful particularly in developing countries for the conservation of vaccines and blood. As photovoltaic systems do not require special maintenance and are easy to install, they are used in Power provision (especially lighting) for houses and mountain refuges [33].

It can be said that solar cells have many benefits, including:

1. The use of solar cells that will be powered by solar energy will provide in the disbursements and bills of houses, offices, factories and protect citizens from high electricity prices associated with oil prices fluctuations in prices [34].
2. The installation of solar system in any house increases the value of the property and improves the chances of resale [35].
3. Many state governments set up taxes and financial incentives that allow citizens who buy a solar cell system to benefit from these incentives.
4. In remote areas where reliance on miles of exposed wire is costly and difficult in areas with difficult terrain, the use of photovoltaic systems for residential buildings becomes less expensive and very reliable, especially in adverse weather conditions.
5. Photovoltaic systems do not have moving units, and have a long operating life with very little maintenance cost [38].
6. Photovoltaic cells without noise as they are quiet and reduce fossil fuel combustion and operate with costless fuel, which is sunlight [38].
7. Photovoltaic electricity does not produce greenhouse gas emissions, unlike the generators fuelled by fossil diesel and gasoline [40].

Meteorology shows that atmospheric variables such as temperature, solar radiation, humidity, and wind speed do not remain stable or constant throughout the day but change up and down vary considerably [41]. Hence, many researchers adopted the investigation of the effect of the arithmetic mean of the daily change in these variables on the performance of the PV system [42]. The PV module temperature increase significantly reduces the power resulting from the system [43]. This reduction was calculated in the efficiency of the photoelectric system and was found to decrease by 0.03%/°C [44]. Increased cell temperature also caused lower open circuit voltage [45]. The rate of flow of electrons increases as photovoltaic power increases when the photovoltaic cell temperature decreases [46]. Studies have shown that photovoltaic system performance deteriorates when temperature rises [47].Therefore, the size of the system is measured according to the average daily cell temperature of the site [48].

The intensity of solar radiation ranges from 100 to 1000 watts / square meter at a temperature of one degree Celsius. This difference is significant in solar radiation. The photovoltaic energy increases with the increase of solar radiation with temperature stability at one degree Celsius, thus increasing the efficiency of the photoelectric system [49].The short circuit current increases linearly with the radiation level at these conditions [50].

This paper aims to study the effect of solar radiation intensity variation on the performance of a PV panel exposed to the natural climatic conditions. The tests were conducted in Baghdad city – Iraq weather conditions.

Experimental Setup

In the current tests a PV panel, which its specifications are illustrated in Table 1, was used. This panel was connected to a controller with DC load to verify the PV panel's current (I) and voltage (V). Also, two batteries were connected to the controller. These batteries are being charged from the PV panel. The PV temperature was measured using a laser thermometer. PV panel's temperature was taken from its back surface as the direction of the laser beam on the panel's front will cause shade on the cell and reduce its productivity. Ammeter and voltmeter were used to measure both the voltage and current.The measurements were conducted from 6 AM till 6 PM. The solar radiation intensity was measured using the WE300 - Rugged solar radiation transmitter detector (4-20 mm), Range: 0 to 1500 W/m^2; spectral response: 400 to 1100 nm; 22.5 m cable. The ambient air temperature was measured using mercury thermometer.

Table 1. The Used PV Panel Specifications.

Solar module type	APM-P 110-2
Peak power	110 W
Open circuit voltage	21.6 V
Short circuit current	7.0 A
Max. power current	6.4 A
Max. power voltage	17.2 V
Dimensions	1450X720X35
Weight	11.4 kg
Wind resistance	2400 Pa
Operating temperature	-40°C - 90°C

Results and Discussions

Table 2 illustrates some of the recorded measurements for the PV panel, and the relation between the solar radiation intensity with the climatic conditions and PV variables is listed. The table results indicates that maximum efficiency gained from the tested panel was 17.03% when the solar radiation was 369.56 W/m^2 , the PV temperature was 38.93°C, and the ambient temperature was 32.5°C. The high solar radiation flux heated the PV panel above the ambient temperature. From the table it is observed that when the PV temperature was less than 25°C with low solar radiation, the PV panel's efficiency was low.

Fig.1 shows the relation between the solar radiation intensity and the PV panel's electrical power. The power is the mathematical multiplication of current and voltage. In general there is direct relation between solar radiations with power. The peak radiation measured throughout the tests was 1035.29 W/m^2; in this case, the resulted power was 720.27 W. During testing, the weather was sometimes cloudy and in other times it was dusty, the solar radiation dropped sharply to reach 354.01 W/m^2 and the power deteriorated to 208.52 W. After sometime the weather started to be clear, so it is increased with power, as the figure reveals.

Fig.1. The relation between solar radiation (W/m^2) and electrical power (W).

Table 2. Some measured and calculated variables of the PV panel throughout the tests.

Current	Voltage	Power	Ambient temp.	PV temp.	Solar radiation	PV efficiency
A	V	P= I*V(W)	C°	°C	W/m^2	%
0	252	0	27.39	21.56	2.77	0
0.39365	251.12	98.85339	29.39	21.96	52.04	11.95774
1.43243	247.16	354.0394	30.51	31.23	221.36	15.96191
2.57014	245.42	630.7638	32.5	38.93	369.56	17.0339
3.42003	245.53	839.72	32.7	45.9	556.47	15.06
3.99457	245.46	980.5072	33.35	52.16	651.39	15.02249
4.18169	245.41	1026.229	34.24	55.93	689.38	14.85654
4.18024	247.74	1035.613	34.94	56.29	720.27	14.34942
3.85506	247.56	954.3587	34.75	53.06	208.52	15.67685
2.98498	247.82	739.7377	34.24	49.25	453.21	16.28961
2.11876	245.64	520.4522	33.18	45.03	91.72	16.63033
0.99168	248.94	246.8688	32.03	36.03	69.04	15.68599
0.17916	251.98	45.14474	31.1	23.92	19.5	13.10494

Fig. 2 shows the relation between PV panel's temperature and the solar radiation intensity. At the begging of measuring period, the solar radiation was low as at 52.04 W/m^2 and the PV temperature was near the ambient temperature. With time progress, the PV temperature started to increase as the solar radiation increased. The maximum PV panel's temperature achieved was 56.29°C when the solar radiation was 720.27 W/m^2. There is a directly relation between the solar radiation and PV cell temperature. The solar radiation is divided into two main parts; the little one is used to generate electricity from the panel while the large part is used to heat up the panel causing elevated temperatures.

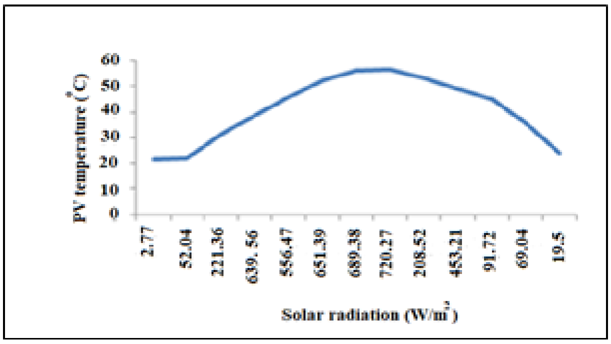

Fig. 2. The relation between the solar radiation intensity and the panel temperature.

Fig. 3 manifests the ambient temperature variation with time through the measuring period. The ambient temperature was stable in the range 29-35°C through the time 6 AM to 6 PM. The ambient temperature peak was between 1 to 2 PM.

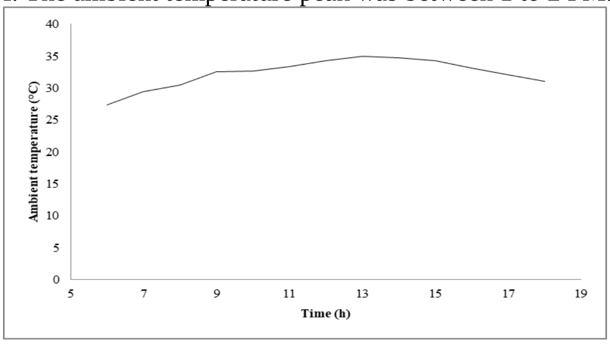

Fig. 3. The relation between the day time and the ambient temperature.

Fig. 4 represents the relation between the PV temperature and daytime. At the begging from 6-7 AM the PV temperature was constant because the solar radiation at its minimum values as Fig. 5 will show. Then the PV temperature start increase with time until it reach the maximum point at 1 PM with 56.29°C, because the sun was direct to the PV cell. After that, by the sun position changed, the PV cell temperature started dropping until it reached 23.92°C at 6 PM.

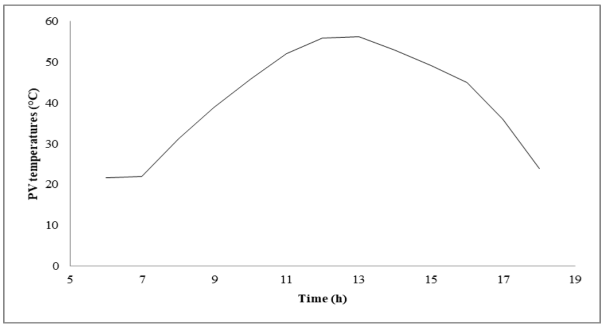

Fig. 4. The relation between the day time and the PV panel's temperature.

Fig. 5 shows the relation between the daytime and the solar radiation intensity through the measured period. In general there is direct relation between solar radiation variations with time. The peak radiation received was 720 W/m^2 at 1 PM. After the peak solar intensity was reached it starts to decline until the solar radiation reached near aero W/m^2 at 6 PM (near the sunset). From watching figures 4 & 5 we observe a similar trend for both the solar radiation intensity and the PV temperature, which means that the solar radiation intensity has the main impact on the PV panel temperature, and as a result, it has the main impact on its efficiency.

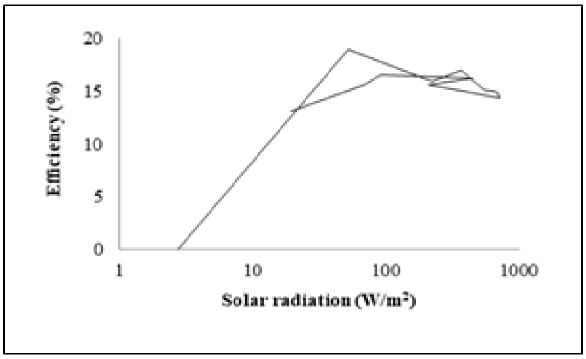

Fig. 5. The relation between the solar radiation and PV panel's efficiency.

Conclusions

The solar cell depends on the solar radiation in generating electricity, so it is related to sunlight and any obstacle that generate shadow on the PV array will affect its efficiency, and this most disadvantage of solar energy.

The PV panels depend on the weather conditions, it's cloudy or not, it is dusty or not. Also, it depends on seasons, where the solar radiation varies from season to another.

The study results show that there is a direct proportionality between solar flux and output current as well as solar flux and efficiency of solar panel. All in all, using the PV cells and sun light to produce power and energy become very common and most effective way regarding to expenses or environment and renewable. The clean solar energy technologies will have huge longer-term benefits.

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