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The Impact of Solar Radiation Azimuth Angle on the PV Outcomes in Erbil City-Northern Iraq

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Abstract— *In this study, the effect of azimuth angle of solar radiation on solar cell output was investigated. The azimuth angle varies from season to season during the year, so the study extended throughout 2017, and the readings were conducted in Erbil and four days of each month. The results showed that the azimuth angle of the city of Erbil changes in the range of 0.4 degrees during the year. The change of the angle mentioned affects the voltages produced from the solar cell. The temperature of the cell is affected by solar radiation and therefore it is found to rise above the temperature of air up to 20 degrees depending on wind movement, which was low during the study.*

Keywords— *Erbil City, Northern Iraq, azimuth angle, solar radiation, PV panel, voltage, current.*

I. INTRODUCTION

The world is living a critical phase of climate change that has begun to affect societies and has reached individuals [1]. The work of man and the direct impact on the environment by burning fossil fuels for energy purposes, whether electricity or transportation caused high environmental pollution in addition to global warming, which resulted in the climate change [2], [3]. The constant need for energy for the purposes of comfort from lighting, conditioning, and heating in addition to the operation of factories began to have a negative impact on humanity, despite its importance to human life [4]. It has become necessary to switch to environmentally friendly sources that do not produce pollution as they are cheap and available everywhere and we mean renewable energies such as solar energy and wind power [5].

A small part of the sun's energy reaches the earth, which is available for many applications, such as increasing water temperature in domestic water heaters [6], [7], heating a salt gradient solar pond [8], [9], solar water desalination and treatment [10-14], generating electricity by heating a concentrated plant [15-19], using a solar chimney [20-22], or moving free electrons in the photovoltaic cell [23-25]. Sunlight also provides energy for natural processes such as photosynthesis, air heating, and Trombe walls [26-32]. Solar energy is a safe, clean, and available year round. This environmentally friendly energy is of great importance to the world, especially in the context of rising fossil fuel costs and volatile oil prices for the past period [33], as well as the critical climate of burning fossil fuels, whether coal, oil or natural gas [34-35].

Total solar radiation falling to the surface of the earth is direct and diffuse radiation, consisting of radiation with short and long waves. Ground objects and clouds can absorb short-wave radiation and re-emit it as long-wave radiation [36], [37]. Direct radiation reaches the Earth's surface from the solar beam without any interaction with particles in the atmosphere. A portion of radiation outside the solar beam is dispersed and dispersed by gases and aerosols (which includes dust particles, as well as particles of sulfates, soot, marine salt particles, pollen, etc.). As part of the radiation is reflected from the terrain thus this part of the radiation is more important in mountain areas. Direct short wave radiation is the most important element of global radiation because it contributes the most energy balance, and other components depend on it either directly or indirectly [38-40].

Photovoltaic cells (PV) are a method of converting solar energy into electricity (direct current using semi-conductive materials that show light effect, a phenomenon usually studied in physics, photochemistry and electrical chemistry. The photovoltaic system uses solar panels consisting of a number of solar cells to provide usable solar energy [41], [42].

In 1839, the French physicist Edmund Beckerle observed the photoelectric effect, which found that some materials produced small amounts of electricity when exposed to light. In 1905, Albert Einstein described the nature of light and the photoelectric effect of photonic technology, which was later awarded the Nobel Prize in physics. The first photovoltaic unit was built by Bell Laboratories in 1954. It was described as a solar battery and was mostly just curious because it was too expensive to get widespread use [43].

In 2013, the world's rapidly growing solar photovoltaic capacity increased by 38% to 139 GW. This is enough to generate at least 160 terawatt / hour (TWH) or about 0.85% of the demand for electricity on the planet. As of early 2015, solar PV installed worldwide has increased to 200 GW. China, followed by Japan and the United States, is now the fastest growing market, while Germany remains the world's largest producer, contributing nearly 6 percent to its national electricity demand [44].

Photovoltaic solar power is now, after hydropower and wind power, the third most important source of renewable energy in terms of installed capacity globally [45], [46]. More than 100 countries are using solar photovoltaic [47]. Installations may be installed on the ground (sometimes integrated with agriculture and grazing) or incorporated into roof or building walls (either integrated photovoltaic units or simply on the surface) [48].

Photovoltaic cells have many applications at present. They are used in water pumping installations (this application is very important in developing countries) and it is increasingly important in the off-road or rural areas [49-52]. It is also currently used in cathodic protection applications for gas pipes, oil pipes, and other types of pipes. It is also energy saving in general, especially for limited electrical charges (within a few kilowatts) always in areas far from the grid or where power cannot be relied on (intermittent power supply) [53-55].

Photovoltaic cells are used in radio/television relay stations: telephone devices; stations for monitoring and transmitting data (meteorological, seismic, water levels, indicating fires) [56]. Solar cells are very useful for civil services such as street lighting, parks, and traffic signs. Photovoltaic systems are also used in the medical sector, especially in remote areas, to provide electricity for the preservation of vaccines and blood [57]. In addition to it provides energy (especially lighting) for homes and mountain shelters. Many solar applications can be used in developing countries: photovoltaic systems do not require special maintenance and are easy to install [58].

Solar cells are affected by ambient conditions such as temperature [59], solar radiation [60], relative humidity [61], [62], wind [63], dust and dirt [64]. The Iraqi environment is characterized by high solar radiation and high temperatures in summer [65]. The high temperature of the solar cell reduces its productivity clearly [66], [67]. Recent studies have focused on the topic of cell temperature reduction using PV/T systems and the results are promising in this regard [68-72]. Relative humidity is moderate most days of the year, as is the wind. However, Iraqi airspace is dusty most of the year, due to drought, desertification and increasing salinity of water [73], [74]. Several studies have been conducted on the impact of dust on Iraqi solar cells and concluded that periodic cleaning with good cleaning agents can minimize the effect of this agent [75-79].

Iraq has a high level of "clarity in the sky" and receives daily solar radiation ranging from 50,000 to 6,000 watts / m2 per day in July to 2500-3000 watt / m2 per day in January, making it one of the highest energy densities solar powers in the world [80].

In Iraq, minimum solar applications are being used in a number of locations to provide lighting, water heating and water pumping [81]. However, many studies by Iraqi researchers have estimated that the economic potential of this source of energy is much greater and can generate 4.1 terawatt hours per year if efficiently exploited [82]. Many scientific research centers in Iraq have helped Iraqi universities to study solar radiation in various locations in the country. Many of the sites that have the greatest amount of solar energy have been identified and photovoltaic stations can be established [83-85]. More importantly, the cost of producing energy at these three sites is competitive with current diesel-based power generation systems. Environmentally, if this type of energy replaces the current system of diesel and natural gas generators in remote areas, studies show that this will lead to a reduction of 11,000 tons of greenhouse gas emissions per year [86].

According to Ref. [87], Iraq has not installed any worthy renewable energy capabilities other than dams that use hydraulic power to generate electricity. Solar energy is used only for water heating systems for private homes and some government departments. According to the source 2012 Iraq seeks to diversify electricity generation and reduce reliance on diesel and gas [88], [89].

The paper aims to study practically the effect of the daily average temperature variation on the performances of the optimized system. The tests were conducted in Irbil city (Northern Iraq). The tests expanded on a period of year 2017 to evaluate the differences in PV cell outcomes through the year.

II. EXPERIMENTAL SETUP

A monocrystalline PV panels was used in the probe to assess the effect of temperature changes on cell efficiency. Table I lists the specifications of the board used. The following parts of the laboratory equipment were used: • monocrystalline photoelectric panel • control panel • acid storage batteries storage system • charge controller DC / DC rated capacity 1 kW • Power loads water pump & lighting.

TABLE I. Summary of the design and sizing parameters of the PV system.

Parameters	Units	PV panel
Out peak power	W_p	10
Open circuit voltage	V	21.9
Short circuit current	A	0.63
No. of cells	-	36
Power tolerance	%	0%-3%
Max. power voltage	V	17.5
Max. power current	A	0.57
size of module	mm	475x282x28
Weight of module	kg	1.5

A. *Experimental Procedure*

The voltage of the current PV voltage and voltage was measured in the normal weather conditions of Erbil, Iraq. In all weather conditions the PV plate was a clean plate. A blower was used to remove the accumulated particles from dust and contaminants on the entire PV cell surfaces. The cell was also cleaned with sodium solution and as the Ref. [90] advised. The performance of the used PV panels is affected by seasonal variations and several things such as air temperature, solar radiation, short circuit current, and azimuth angle. However, the testes were distributed to ensure equality by conducting them at a specific time. The tests were conducted every (3, 10, 17, and 24) of each month during the whole year.

III. RESULTS AND DISCUSSIONS

Fig. 1 shows the relationship between the maximum recorded open circuit voltages distributed on the months of the year. From January to April, there was a considerable fall in the values of the voltage. Moreover, it went up and down widely over the next two months. However, there was a significant increase in the values of the voltage between July and December. Generally, it is seen that the voltage decreases by increasing the temperature, which has a direct influence on voltage. The effect of temperature on voltage is associated with other properties of the PV panel’s material such as conductor and semiconductor which changes accordingly with the temperature

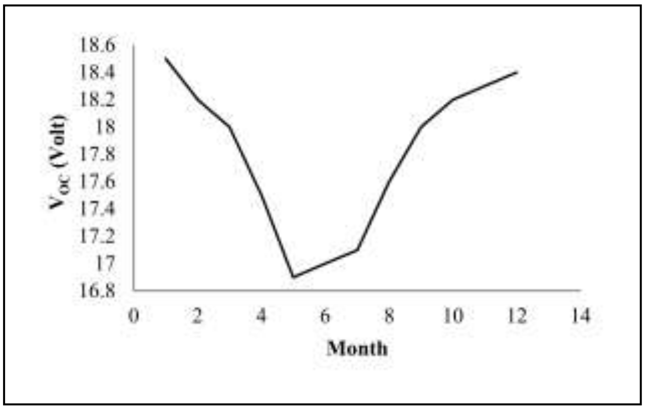

Fig. 1. The open circuit voltage distribution through the year.

On the other hand, Fig. 2 shows the distribution of azimuth angle with the months of year 2017. The period between January and April saw a dramatic growth in the values of the azimuth angle. In addition, from May to July the values of azimuth angle remained fairly static at approximately 60º. However, the values of azimuth angle continued to fall steadily over the next five months until it reached its lowest point in December. The different in the values comes from several things for example, as semiconductor decreases the temperature increases and hence this results as a decrease in the open circuit voltage of the semiconductor. Due to this decrease in the band gap of semiconductor more incident energy is absorbed by the semiconductor hence it requires less energy to raise carriers to the conduction band. This results in the large photo current through the semiconductor which consequently implies that there is decrease in the voltage (from ohm's law). The temperature also affects the resistance of the conductor. The resistance increases by increasing the temperature. Also the humidity can effect on the performance of the inductors so as the PV's current, voltage and power output are decreased, the relative humidity increased.

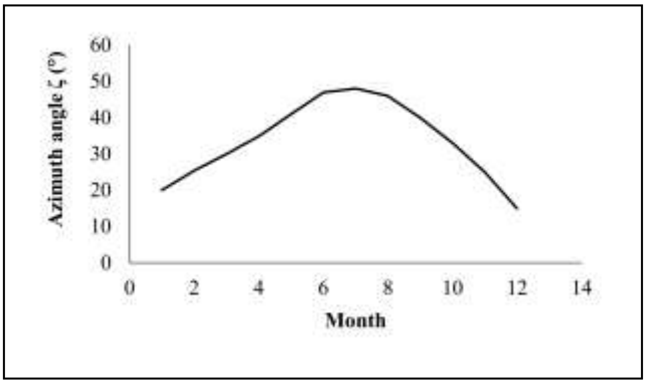

Fig. 2. The azimuth angle distribution through months.

Fig. 3 shows the azimuth angle relations with voltage. The figure declares that the azimuth angle varies in a narrow range while the range of voltage distribution is wider. The changes in voltage with any variation in azimuth angle are large due to the higher solar radiation reached the PV cell.

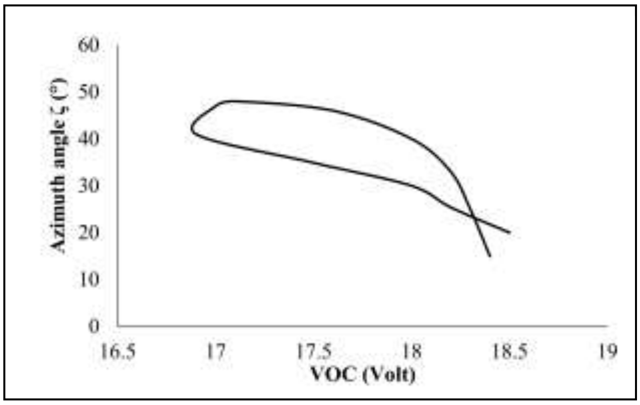

Fig. 3. The azimuth angle relation with open circuit voltage.

Fig. 4 represents the maximum voltage achieved for each month of 2017. The maximum voltage reached was at January as the air temperature is low and the solar radiation in this period is calm. The minimum voltage achieved at August as this month represents the higher solar radiation intensity and air temperature in Erbil. The voltage variation through the year is limited in a range of 0.4 volt.

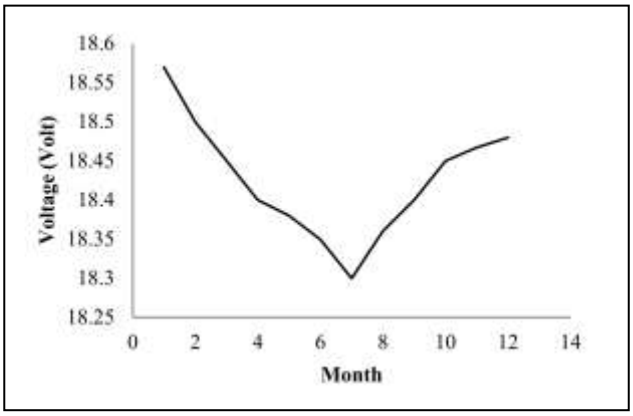

Fig. 4. The voltage distribution through the months of 2007.

Table II lists the practical measures of the surroundings variables and the PV outcomes. The measurements reveal high reduction in the current with the months of June and July while the variation of months has no significant influence on the voltage. The tested PV panel efficiency fluctuated between 13.1 to 17%. This difference depends on solar radiation and panel temperature as well as the air temperature. The PV cell temperature exceeded the air temperature by 17 to 20 ºC due to the high solar radiation intensity and low cooling due to low air movement.

IV. CONCLUSIONS

The study investigated the effect of azimuth angle of the solar radiation on the cell temperature and its outcomes. The results reveal that at the azimuth angle variation is limited through the year but its effect on the resulted voltage is high. The efficiency is osculated between 13 to 17%. The maximum efficiency achieved at January and the minimum ones were at June and July. The photovoltaic cell temperature exceeded the air temperature in a range of 17 to 20ºC due to high solar radiation intensity and low cooling effect of the wind in the studied area.

TABLE II. The practical measurements.

Month	Current	Voltage	Power	room Temperature	PV Temperature	solar radiation	efficiency
	A	V	P= I*V(W)	ºC	ºC	W/m^2	%
Jan.	0.39365	25.12	9.88	29.39	21.96	52.04	18.95774
Feb.	0.43243	24.16	10.44	30.51	31.23	221.36	15.96191
March	0.57014	24.42	13.919	32.5	38.93	369.56	17.0339
April	0.42003	24.53	10.302	32.7	45.9	556.47	15.06
May	0.399457	24.46	9.77	33.35	52.16	651.39	15.02249
June	0.418169	24.41	10.203	34.24	55.93	689.38	14.85654
July	0.418024	24.74	10.34	34.94	56.29	720.27	14.34942
August	0.385506	24.56	9.467	34.75	53.06	208.52	15.67685
Sept.	0.298498	24.82	7.406	34.24	49.25	453.21	16.28961
Oct.	0.211876	24.64	9.835	33.18	45.03	91.72	16.63033
Nov.	0.399168	24.94	9.954	32.03	36.03	69.04	15.68599
Dec.	0.317916	25.98	8.2495	31.1	23.92	19.5	13.10494

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