The effect of high temperature on the efficiency of solar cell, study at Aljufra-Libya

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Abstract

this paper presents a study and analysis of the performance of a solar panel in practice according to the weather conditions of the city of Aljfura. The power output from the photovoltaic cell mainly depends on the light intensity, the cell temperature, the panel's orientation, its size and surface conditions. The temperature of solar cell has direct influence on the power output of a solar PV module. Crystalline solar cells are the main cell technology and usually come with a temperature coefficient of the maximum output power of -0.5% degree Celsius. Generally, the rated power indicated on the module's label is measured at 25C°. Power losses increase with any temperature increase above 25 C°. Most installed solar modules in hot and sunny countries reach higher temperatures than 25C°. Libya is one of the sunny countries where the temperature easily reaches higher than 40 C°. The climate of Aljfura is generally hot and dry in summer, autumn, and spring, however, it is cold and rare rain in winter. The operating temperature plays a key role in the photovoltaic conversion process.

Keywords — *photovoltaic, temperature, silicon solar cell, semiconductor, power output.*

تأثير الحرارة العالية على كفائه الالواح الشمسية: دراسة في الجفرة ليبيا

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المستخلص:

تقدم هذه الورقة دراسة وتحليل لأداء الألواح الشمسية عمليا حسب الظروف الجوية لمدينة الجفرة في ليبيا. يعتمد خرج الخلية الكهروضوئية بشكل أساسي على شدة الضوء الساقط على الخلية وحجمها ودرجة حرارة الخلية. لدرجة حرارة الخلية الشمسية تأثير مباشر على كفاءتها وجهد خرجها. تصنع الخلايا الشمسية البلورية بتقنية مع معامل درجة حرارة- 0.5% وتحث درجة حرارة $25C^{o}$. الطاقة المفقودة من الخلية تزداد طرديا مع زيادة درجة الحرارة عن $25C^{o}$ معظم وحدات الطاقة الشمسية المتبتة قي البلدان الحارة والمشمسة تصل درجة حرارتها الي أكثر من $25C^{o}$. في ليبيا حيث الطفس الحار المشمس أغلب أيام السنة بأستتناء فصل الشناء تصل درجة الحرارة الي أعلا من $40C^{o}$. تمث هذه الدراسة في منطقة الجفرة والتي يتميز طقسها بالجفاف والحرارة العالية في الربيع والخريف والصيف بينما الشتاء بارد ونادر الامطار. أن حرارة تشغيل اللوح الشمسي تعمل دور رئيسي في عملية التحويل الكهروضوئي.

الكلمات المفتاحييه: الخلايا الكهروضوئية، درجة الحرارة، الخليه السيليكونية، أشباه الموصلات، الطاقة الخارجه.

I. INTRODACTION

As a solution to electrical network failure, Libya trying to diversify their economy and reduce their dependency on oil as a source of income, and energy generation, in order to develop more sustainable and knowledge-based economy. Photovoltaics (PV) are the field of technology and research related to the application of solar cells for energy by converting sunlight directly into electricity [1]. The photovoltaic effect can be interpreted as follows: it is the generation of an electromotive force as a result of the absorbing light. The photovoltaic effect can be observed by variety of materials. However, semiconductor materials have the best performance in sunlight. The majority of them have low electrical resistance when they are exposed to light [2][3]. These technologies have the following advantages that make them more attractive devices to produce electricity for the present and the future: no moving parts, no emission or waste during operating, no noise pollution, low maintenance and unlimited supply [4].

II. SOLAR RADIATION

Global solar radiation is defined as the total amount of solar energy received on the earth's surface [1]. There is more than enough solar radiation available around the world to satisfy the demand for solar power systems. The proportion of the sun's rays that reaches the earth's surface can satisfy global energy consumption 10,000 times over. On average, each square metre of land is exposed to enough sunlight to receive 1,700 kWh of energy every year [2]. Sufficient information about the available solar radiation at a Particular location on earth is used to study, plan and design solar energy applications. In addition, such information is used for prediction of the efficiency of installed solar devices.

Total global solar radiation is comprised of the direct, diffuse (reflected) components:

- Direct radiation is the component of total global solar radiation incident on a surface normal to the sun's rays that travels in parallel lines directly from the sun.

- Diffuse radiation is the component of the total global solar radiation incident on a surface that is scattered or reflected. This component also includes ground reflected radiation.

As the Fig. 1shows, approximately 30% of extraterrestrial solar power is absorbed or reflected by the atmosphere before reaching the earth's surface. Considering the radiation exchange only, the 5 main factors in order of importance are:

1. Direct short wave radiation from the Sun.

2. Diffuse short wave radiation from Sky.

3. Reflected; short wave radiation from ground and surroundings.

4. Long wave radiation from Sky, heated ground and nearby objects.

5. Outgoing long wave radiation from building and ground surfaces to the Sky.

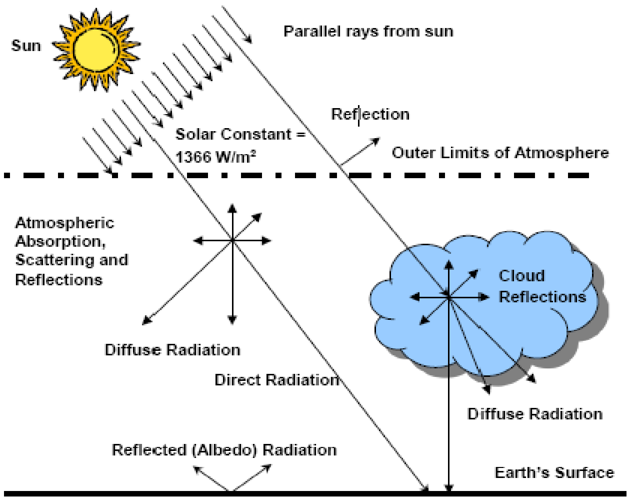

Fig. 1total global solar radiation (direct and diffuse)

Solar power effects vary significantly with altitude latitude, time of day and year, air pollutions, weather patterns and wavelength of solar radiation.

III. THE LOCATION OF LIBYA

Libya stretches over a latitude of $19 - 33o\ North$ and $9 - 25o\ E$, longitude and its $10\ and\ 700\ m$ height above sea level [11]. Libya is located in the middle of North Africa with a huge area of 1,759,540 Km^2 and a long coast of a length of 1,900 Km on the Mediterranean Sea; it has significant potential for harnessing solar energy [12]. Solar energy is considered to be one of the main resources due to the location of Libya on the cancer orbit line with exposure to the sun's rays throughout the year and with long hours during the day. Libyan position is favoured to receive abundant solar radiation. In the coastal regions, the daily average solar radiation on a horizontal plane on an average is 7.1 kWh/m^2 /day and in the southern region, it is 8.1 kWh/m^2/day as shown in Fig. 2. According to Libyan renewable energy authority, the average duration of sunlight is more than 3,000 hours per year. This is equivalent to a layer of 25 cm of crude oil per year on the land surface [3].

The desert accounts of 88 percent of the total area in Libya, where there is a high potentiality of solar and wind energy which can be used to generate electricity thermal, photovoltaic and solar energy conversions. Moreover, it has been estimated that every year, each square kilometre (Km^2) of desert in the Middle East/ North Africa region receives solar energy equivalent to 1.5 million barrels of crude oil [1]. Radiation map over the world it's appear that Libya in high sun radiation as shown in table 1.

TABLE I AVERAGE MONTHLY RADIATION (kWh/m^2) IN DIFFERENT LIBYA LOCATIONS [4]

Month	Tripoli	Sabha	Gath	Algbah	Jalow	Alkofra	Hoon	Chahat
Jan	2.95	4.18	4.00	3.80	3.66	4.43	3.54	3.89
Feb	3.87	4.88	4.80	4.70	4.54	5.38	4.22	4.70
Mar	5.00	5.81	4.70	5.59	5.37	6.04	5.10	5.59
Apr	5.97	6.68	6.30	6.71	6.56	6.86	6.19	6.71
May	6.45	6.65	6.30	7.10	5.74	7.24	6.61	7.10
Jun	7.00	7.35	6.60	7.67	7.16	7.43	7.06	7.67
Jul	7.05	7.26	7.17	7.66	7.17	7.25	7.09	7.66
Aug	6.47	6.96	6.30	7.10	6.74	7.19	6.969	7.10
Sep	5.48	6.51	5.30	6.22	4.83	6.45	5.91	6.22
Nov	4.00	5.56	5.10	5.13	4.83	5.67	4.72	5.13
Oct	3.15	4.75	4.10	4.00	4.86	4.70	3.80	4.00

Month	Tripoli	Sabha	Gath	Algbah	Jalow	Alkofra	Hoon	Chahat
Dec	1.83	3.97	3.50	3.51	3.86	3.99	3.09	3.51
Averg	4.94	3.44	5.36	5.77	3.44	6.05	5.34	5.77

A. Libya climate

As the fig .2 shows, The Mediterranean Sea and the Sahara Desert are the most important features of Libya’s geography in determining climatic conditions, which include abrupt weather changes and sudden weather events across the country. The northern Mediterranean areas of Libya have dry summers and mild winters, with the majority of the precipitation falling in the winter.

The highlands near Tripoli and Benghazi experience cooler temperatures and receive the most rain of any region in Libya. The interior desert experiences hot, scorching temperatures with extreme variation within a day. Rain is rare and irregular in these areas.

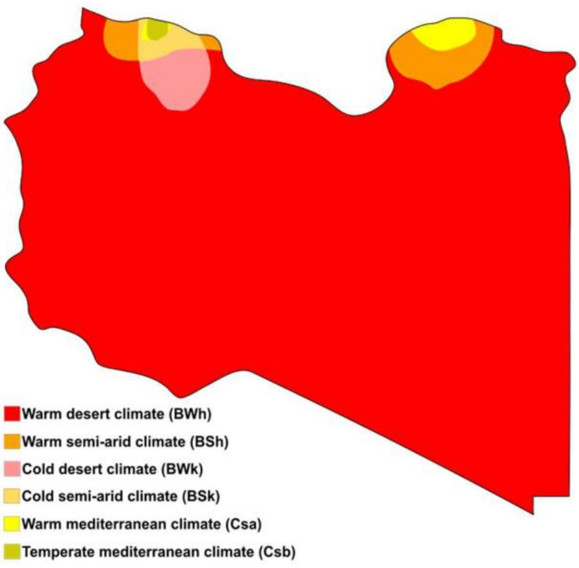

Fig .2 Libya climate zones

B. Libyan electricity grid

The Libyan national electric grid consists of a high voltage network of about 12,000 Km, a medium voltage network of about 12,500 Km and 7,000 Km of low voltage network. Some village and remote areas which are located far away from these networks cannot be connected to the grid due to economic reasons, so that, PVs connected near this loads.fig 3 , shows the Libyan national grid at 220KV and 400KV.

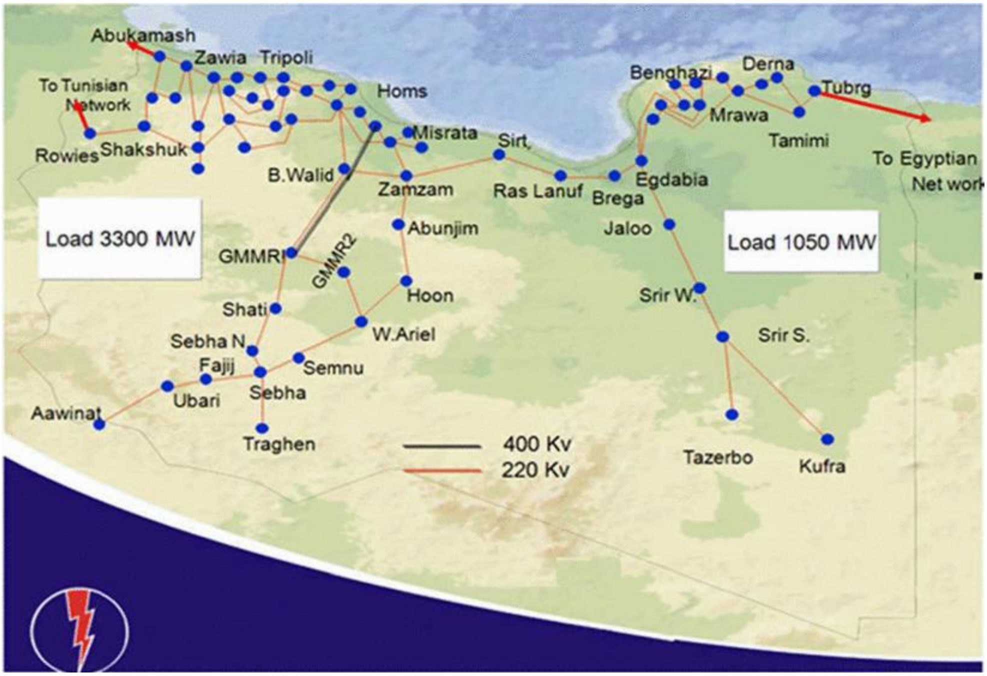

Fig .3 Libyan national grid (220&400KV) [2]

IV. CHARACTERIZATION OF SOLAR CELL

Solar cells are devices made from materials which have the ability to generate electric power when exposed to the light. Light consists of packets of energy, called photons. Photon’s energy depends on light colour or frequency. Silicon p-n junction solar cell serves as a reference device for all solar cells. P-n junction is a device formed by fusing a semiconductor doped with acceptor impurities (p-type semiconductor) with a material doped with donor impurities (n-type semiconductor). A typical schematic representative of a solar cell is shown in fig.4. It consists of a shallow p-n junction formed on the surface by diffusion or ion implantation, a front ohmic contact stripe and fingers, a back ohmic contact that covers the entire back surface, and the front surface is coated with appropriate materials to reduce reflection and to decrease surface recombination [8].

Light enters the semiconductor material through the n region and generates an electron-hole pair (EHP) in the material due to the photoelectric effect. The n region is designed to be thin while the depletion region is thick. If the EHP is generated in the depletion region, the built-in electric field drifts the electron and hole apart. The result is a current through the device called the photocurrent [9].

The current produced by light in ideal cell ($R_S = 0,\ R_{SH} = \infty$) is given by

$$I = -I_L + I_D\left(1 - e^{V/V_T}\right) \quad (1)$$

Where: I_L is the light-generated current, $I_D\left(1 - e^{V/V_T}\right)$ is the reverse diode current.

An equivalent circuit of the solar cell Eq. (9) can be drawn as shown in fig.5. The power delivered to the load is given by[8].

$$\mathrm{P = IV = -VI_L + I_D V\left(e^{V/V_T} - 1\right)} \quad (2)$$

A. Photovoltaic Cell Parameters

From the current-voltage characteristics of a solar cell, the parameters can be defined as following [10]:

- Open-circuit voltage (V_{oc}): is the maximum voltage available from a solar cell where current is zero. It increase with the substrate doping

$$V_{oc} = V_T \ln(1 + \frac{I_L}{I_0}) \quad (3)$$

- The short-circuit current (I_{sc}) is the current through the solar cell when the voltage across the solar cell is zero. It is directly proportional to the available sunlight.

$$I_{sc} = -I$$

- Fill factor is between 0.7and 0.8 for an ideal cell. It determine by

$$ff = \frac{V_{mp} I_{mp}}{I_{sc} V_{oc}} \quad (4)$$

Where: V_{mp} the current at maximum power, I_{mp} the voltage at maximum power.

- Cell efficiency is an important parameter to know the cell performance. It is the percentage of power converted from absorbed light to electrical energy.

$$\text{Solar Cell efficiency}=\frac{V_{mp}I_{mp}}{P_{in}}\times 100\% \qquad (5)$$

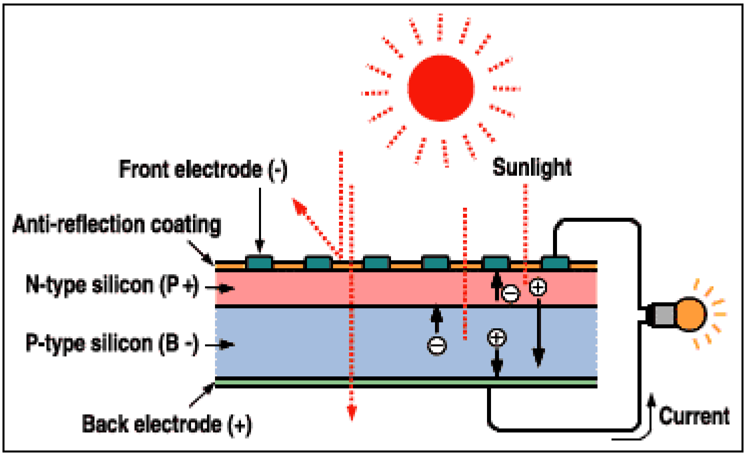

Fig .4 Silicon p-n junction solar cells

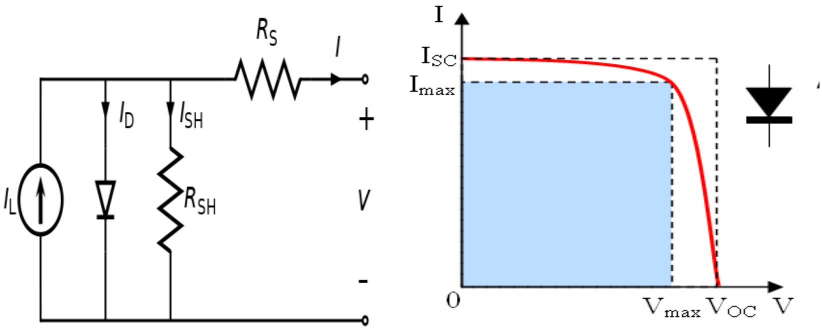

Fig .5 Equivalent circuit of the solar cell and current-voltage characteristics of a solar cell under illumination

V. RESULTS AND DISCUSS

The experimental investigations were preformed in summer season of 2022, and were conducted in the electronic lab. in College of Engineering

Technology in Houn, Libya at 29° 12' 45° N and 15° 94' 02° E. The experimental was for two days, 30/6/2022 and 2/7/2022 for 6 hours, period from 10 am to 4 p.

Two similar units of a silicon solar cell were connected in series; the total area is $1.3776m^2$. The voltage rate of each unit is 17.3 V, current 4.6A, maximum power 80W, open circuit voltage21.9V, short circuit current 5.0A and area $0.6888m^2$.

A. PV panel output performance under outdoor condition

In this study, the PV panel output performance was investigated under outdoor condition Fig. 6 Shows photographic view for front side PV panel through outdoor experimental. All data measured and recorded from 10.00 am to 4.00 pm. Fig. 7 Shows the output power of PV panel with distribution PV panel temperature at constant solar irradiance. These figures show the characteristics of current-voltage (I-V) curves based on the various PV panel temperatures. The current-voltage (I-V) was measured in order to calculate the output power produced from PV panel. Both figures show that the output voltage decreases gradually with the increase in panel temperature. However, the increasing output current of PV panel generated with more incident energy absorbed during high temperature. As a results show, the rating power cannot perform 100% caused by the elevated PV panel temperature. The output power was observed in worse condition at a low solar irradiance.

Fig .6 PV panel

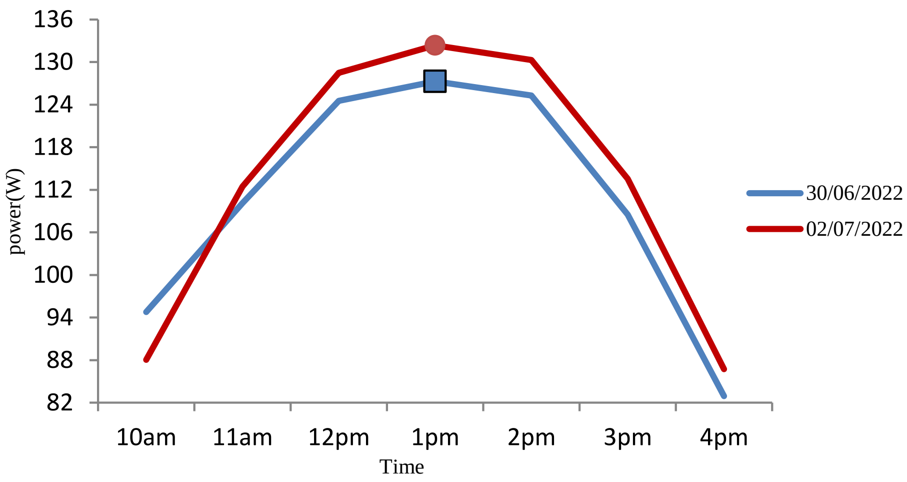

Fig .7 the output power of PV panel

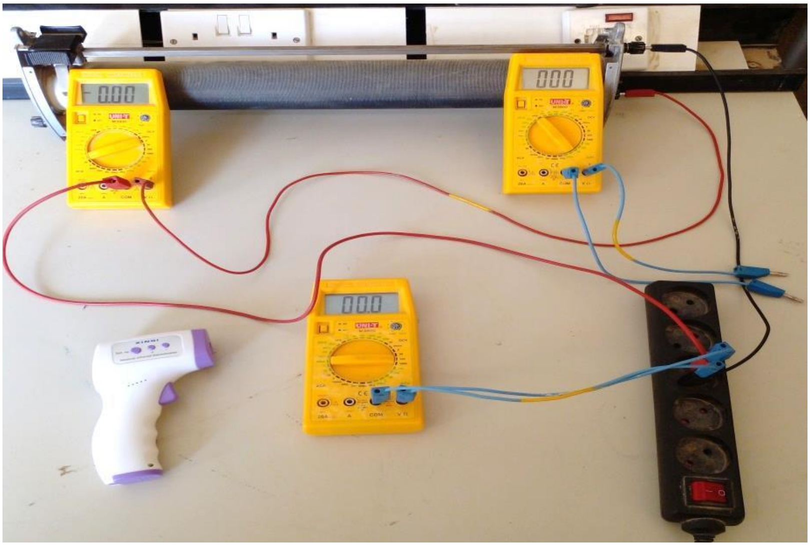

Fig .8 experimental circuit

TABLE II THE OUTPUT OF PV PANLE FOR BOTH DAYS

2022/7/2						2022/6/30					
T(C°)	Isc(A)	Voc(V)	FF	800 W/m^2	1000 W/m^2	T(C°)	Isc(A)	Voc(V)	FF	800 W/m^2	1000 W/m^2
45	2.46	35.8	0.6872	5.49%	4.39%	46.9	2.67	35.5	0.6831	5.87%	4.70%
48.5	3.15	35.7	0.6650	6.78%	5.42%	53.6	3.12	35.3	0.6424	6.41%	5.13%
51.6	3.65	35.2	0.5917	6.89%	5.51%	57.2	3.60	34.6	0.6225	7.03%	5.62%
54.2	3.75	35.3	0.6368	7.64%	6.11%	59.5	3.70	34.4	0.6220	7.18%	5.74%
54	3.65	35.6	0.6330	7.48%	5.98%	55.8	3.57	35.1	0.6355	7.22%	5.78%
50	3.19	35.6	0.6513	6.71%	5.36%	55.3	3.11	34.9	0.6445	6.34%	5.07%
45.4	2.45	35.4	0.6760	5.31%	4.25%	50.8	2.39	34.7	0.6772	5.05%	4.04%

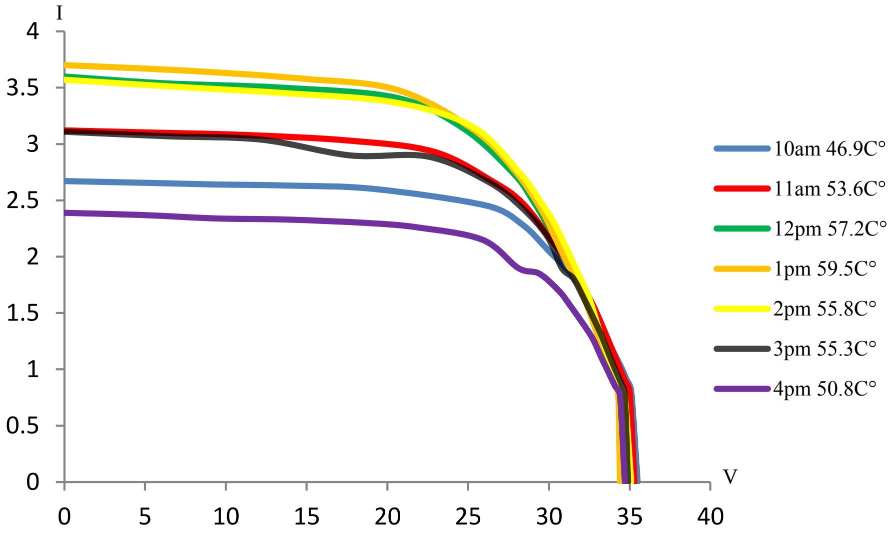

Fig 9 (V-I) curves for various temperatures at 30/6/2022

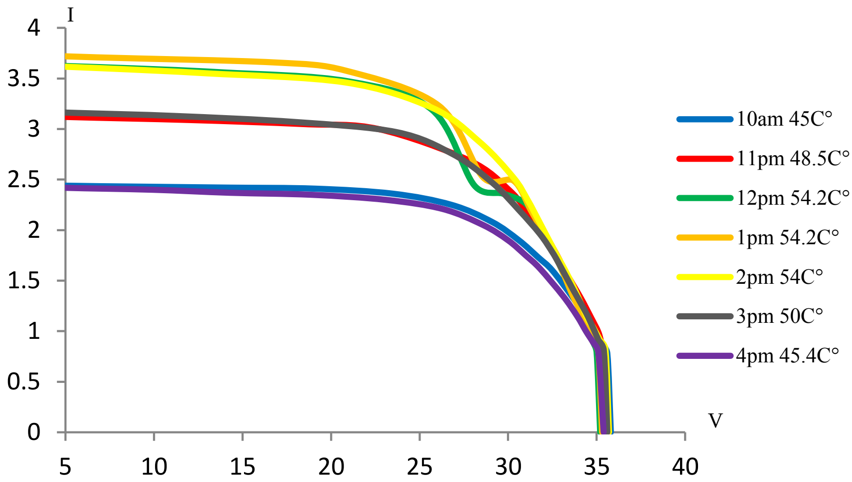

Fig .10 (V-I) curves for various temperatures at 2/7/2022

Fill factor is classified as an indicator in determined quality of PV panel. Typical fill factor values rang is between 0.6 and 0.7[1]. Fig.11 shows the quality of PV module by analysing the range of fill factor. The figure indicates the PV panel performed in good quality firstly with range above 0.68.unfortunatly, when the PV panel temperature starts to increase, the value was dropped to the range between 0.5 and 0.6.decteases in fill factor may indicate problems of the cell in the PV panel. The lowest fill factor found when the PV panel temperature reached at 51.6 C° with 0.58.

Meanwhile, the high fill factor detected in the early morning with 0.69 when the PV panel temperature experienced in low value. Recombination current and ohms resistance is strongly affected in the fill factor for silicon PV panel.

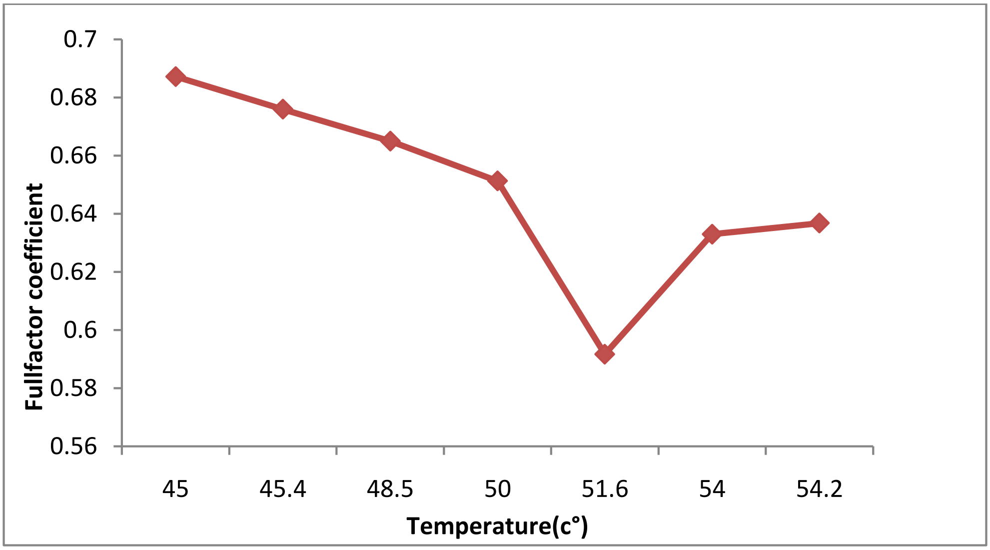

Fig .11 effect temperature on fill factor at 30/6/2022

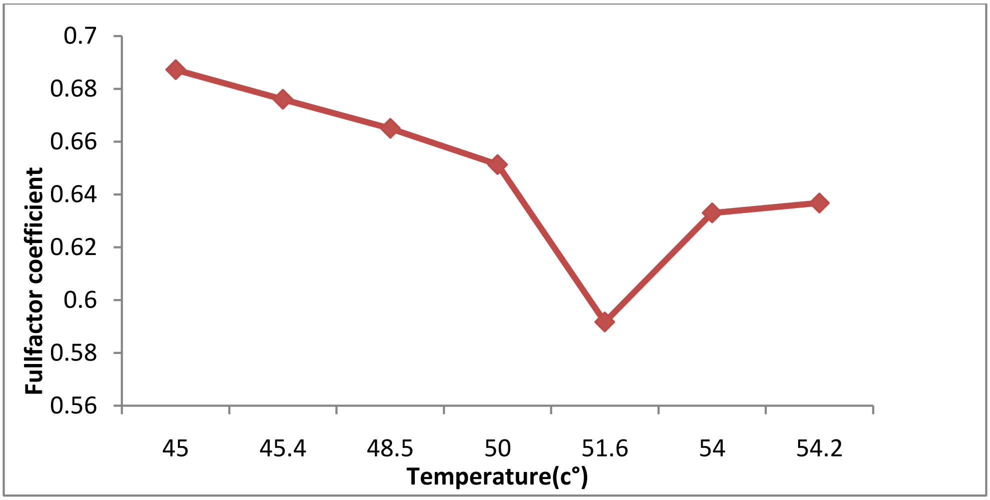

Fig .12 effect temperature on fill factor at 2/7/2022

III. Conclusions

The paper emphasizes that the performance of solar panels is significantly influenced by factors such as light intensity, cell temperature, and environmental conditions. The results in this paper demonstrate there is strongly proved that the PV panel temperature plays a crucial role in output power production. The outdoor experimental shows that the most significant changed by temperature was output voltage which reduces with the elevated

PV panel temperature. Reduction in output voltage causes the production output power of PV panel cannot be generated efficiently even there has increase of the output current. Furthermore, the quality operation of PV panel also decreases with the increasing of PV panel temperature. The literature survey of this paper indicates a comprehensive understanding of solar radiation, the photovoltaic effect, and the significant impact of temperature on solar cell efficiency, particularly in the context of Aljufra, Libya.

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