Journal of The Faculty of Science and Technology (JFST)
http://journal.oiu.edu.sd/index.php/JFST
https://doi.org/10.52981/jfst.vi7.952
ISSN: 1858 - 6007
مجلة العلوم و التقانة – جامعة أم درمان الإسلامية – وزارة التعليم العالي و البحث العلمي - السودان

Research article **JFST Issue No. 7 (2020) 45 - 55**

The Effect of Solar Radiation and Temperature on Solar Cell Performance in Khartoum state

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Abstract:

In this paper, the performance of solar cells was studied and evaluated . The role of several effects for operation condition such as temperature, sunlight intensity on the solar cells output parameters has been studied. Experimental results showed that relationship between the amount of solar cell output parameters variations such as maximum output power, open circuit voltage, short circuit current, and efficiency in terms of temperature and light intensity.

The measurements were carried out for the intensity of solar radiation in Khartoum area in Sudan, from February month to April month which records the solar radiation in W/m^2, The results were collected from 10 Am to 4 pm, three days per week, data were averaged and also illustrated in the form of graphs of solar radiation as a function of the time of the day.

The operating temperature plays a key role in the photovoltaic conversion process. Both the electrical efficiency and the power output of the solar cell depend on the operating temperature. Solar cell performance decreases with increasing temperature.

Keywords: Solar Cells, Temperature, Light Intensity and Efficiency

Introduction:

Solar radiation arrives on the earth at a maximum flux density of about 1 kW/m^2 in a wavelength band between 0.3μm and 2.5μm, This is called short wave radiation and includes the visible spectrum. For inhabited areas received fluxes vary widely from about 3μm to 30μm, depending on place, time, and weather. The quality of the radiation is characterized by the photon energy of around 2 eV as determined by the 6000 K surface temperature of the sun Radiant energy fluxes relating to the earth's atmospheric and surface temperature are also of the order of 1 kW/m^2 but occur in a wavelength band between about 5 and 25 μm called long wave radiation peaking at about 10μm. The solar spectrum typically extends from the IR to the UV region, but the intensity is not uniform (Solar Energy Materials and Solar Cells, 2012).

The path length of the light in the atmosphere depends on the angle, which will vary with the time of day, This is given by the air mass number (AM) which is the secant of the angle between the sun and the zenith AM0 represents the solar spectrum outside the earth's atmosphere, AM1 is when the angle is zero, i.e. sun is at the zenith and it has an intensity of 0.925 kW m^2. AM2 is when sun is at angle of 60 and its intensity is 0.691 kW m^2.

When the sky is cloudy, the amount of sunlight that is readily convertible into electricity by photovoltaic cell is reduced by at least 50% during thin cirrus cloud cover and by about 75% more during denser cloud cover. At any time of the day (Capar, 2011).

2. Solar Cell External Parameters:

The main parameters that are used to characterize the performance of solar cells are the maximum power, *Pmax*, the short-circuit current density,Isc, the open-circuit voltage, *Voc*, and the fill factor, *FF*. The conversion efficiency, η, is determined from these parameters (Fesharaki et al., 2010).

2.1 Short-Circuit Current:

The short-circuit current, *Isc*, is the current that flows through the external circuit when the electrodes of the solar cell are short circuited. The short-circuit current of a solar cell depends on the photon flux density incident on the solar cell, that is determined by the spectrum of the incident light. The *Isc* depends on the area of the solar cell, the short-circuit current density is often used to describe the maximum current delivered by a solar cell. The maximum current that the solar cell can deliver strongly depends on the optical properties

(absorption in the absorber layer and total reflection) of the solar cell (Razykov et al., 2015).

2.2 Open-Circuit Voltage:

The open-circuit voltage is the voltage at which no current flows through the external circuit. It is the maximum voltage that a solar cell can deliver. The *Voc* corresponds to the forward bias voltage, at which the dark current compensates the photo-current. The *Voc* depends on the photo-generated current density (Bakirci , 2014).

2.4 Fill Factor:

The fill factor is the ratio between the maximum power (Pmax = Vm × Im) and the product of the open-circuit voltage (Voc) and The short-circuit current (Isc) (Siegel et al., 2012).

2.5 Conversion Efficiency:

The conversion efficiency is calculated as the ratio between the generated maximum power and the incident power (Beyer et al., 2014).

$$\frac{P_{max}}{P} = \frac{V_m I_m}{P} = \frac{V_{oc} I_{sc}}{G} \frac{FF}{A} \quad (1)$$

4. Materials and Methods

The one sample of the commercially solar cells is used for experimental measurements. The solar cell was fabricated monocrystalline with surface area of $0.06557\,m^2$ and capacities of 9.0V and 2.5A, respectively.

Voltage-current (I-V) characteristics, output parameters of solar cell and temperature were measured. To obtain of solar cell I-V characteristics, sample was illuminated by different solar radiation and measured by the Eppley Precision Spectral Pyranometer (PSP) has been used in the present measurements, When the instrument is placed in the sun the readings were record solar radiation in w/ m^2 and the results were collected from 10 Am to 4 Pm three days per week,

the results were tabulated and also illustrated in the form of graphs of solar radiation as a function of the time of the day

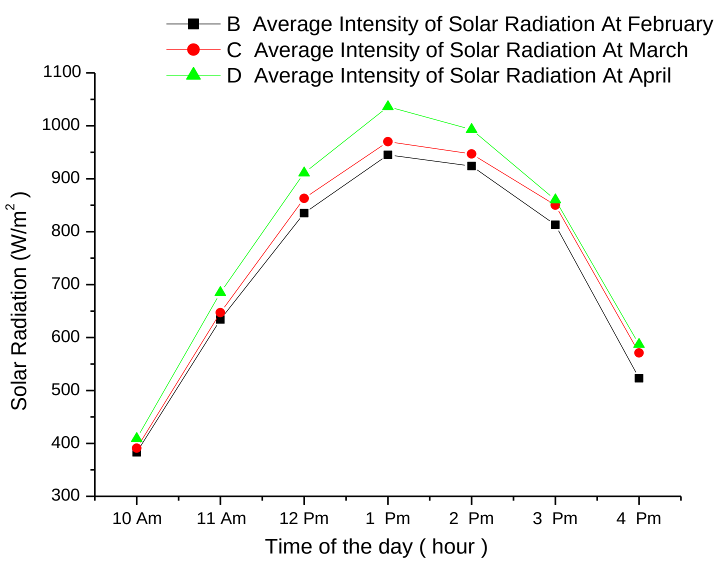
4. Result:

Table 1 and figure 1 Show the relationship between the time of the day and solar radiation in Khartoum state at difference months.

Table 1. Time of The day against Solar Radiation at different month

Time of the day(hour)	February month	March month	April month
Time	Solar Radiation (W/m^2)	Solar Radiation (W/m^2)	Solar Radiation (W/m^2)
10 Am	383	391	409
11 Am	634	647	685
12 Pm	835	863	911
1 Pm	945	970	1036
2 Pm	924	947	993
3 Pm	813	850	860
4 Pm	523	571	587

Figure1. Time of The day against Solar Radiation in Khartoum state



This figure shows the increase and decrease of solar radiation intensity and max intensity at midday at 1 Pm.

Table 2 and figure 2 Show the relationship between the time of the day and Temperature in Khartoum state at difference months.

Table 2. Time of The day against Temperature at different month

Time of the day(hour)	February month	March month	April month
Time	Temper**ature** **(c⁰)**	Temper**ature** **(c⁰)**	Temper**ature** **(c⁰)**
10 Am	26.02	29.87	35.25
11 Am	27.25	31.62	38.00
12 Pm	29.37	33.50	39.25
1 Pm	30.37	34.75	40.50
2 Pm	31.75	36.12	41.44
3 Pm	32.25	36.25	42.37
4 Pm	32.62	36.62	42.38

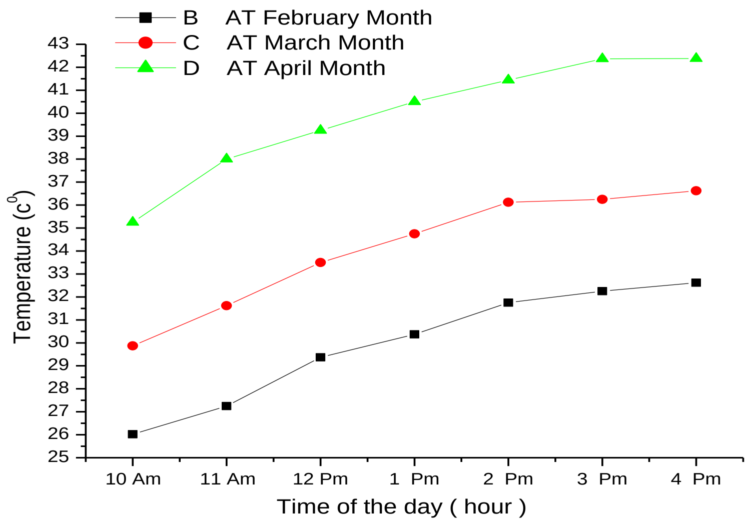


Figure 2. Time of The day against Temperature in Khartoum state

This figure shows the direct increase of temperature from February month to March month then April month with time of the day.

Table 3 and figure 3 Show the relationship between the time of the day and Max Power in Khartoum state at difference months.

Table 3. Time of The day against Max Power at different month

Time of the day (hour)	February month	March month	April month
Time	Max Power (W)	Max Power (W)	Max Power (W)
10 Am	5.788	5.506	4.312
11 Am	6.807	6.683	6.144
12 Pm	6.797	7.275	6.059
1 Pm	7.021	6.996	6.981
2 Pm	6.320	5.957	6.090
3 Pm	4.963	5.427	5.251
4 Pm	4.007	4.044	3.611

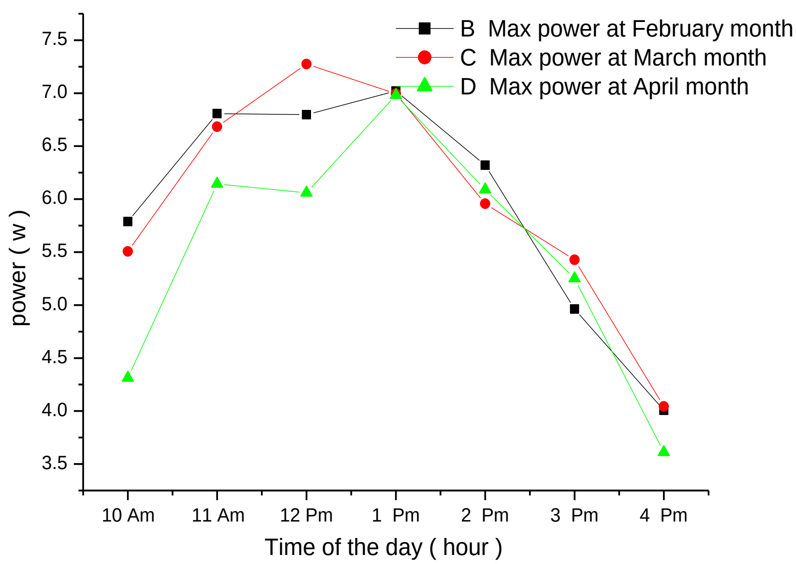


Figure 3. Time of the day against Max Power in Khartoum State

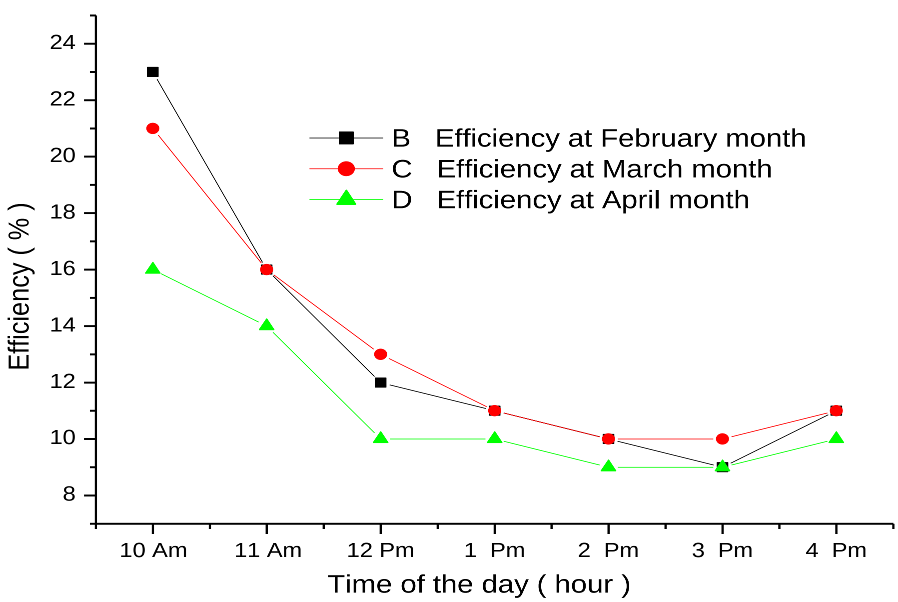
This figure shows the increase and decrease of Max Power from April month to March month then February month with time of the day.

Table 4 and figure 4 Show the relationship between the time of the day and Efficiency in Khartoum state at difference months.

Table 4. Time of The day against Efficiency at different month

Time of the day (hour)	February month	March month	April month
Time	Efficiency (%)	Efficiency (%)	Efficiency (%)
10 Am	23	21	16
11 Am	16	16	14
12 Pm	12	13	10
1 Pm	11	11	10
2 Pm	10	10	9
3 Pm	9	10	9
4 Pm	11	11	10

Figure4. Time of The day against Efficiency in Khartoum state



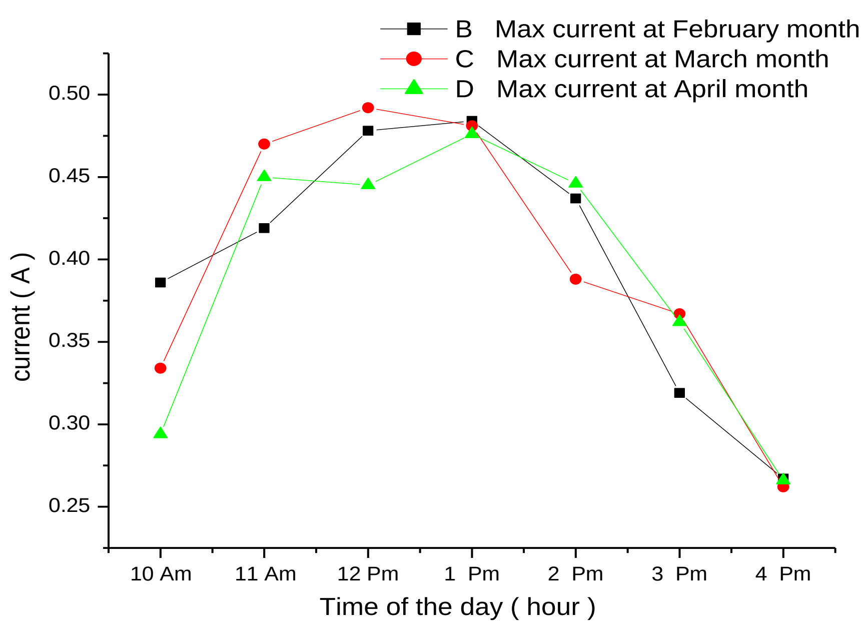
This figure shows the decrease of Efficiency and increase at 4 Pm from April month to February month then March month with time of the day.

Table 5 and figure 5 Show the relationship between the time of the day and Max Current in Khartoum state at difference months.

Table 5. Time of The day against Max Current at different month

Time of the day (hour)	February month	March month	April month
Time	Max Current (A)	Max Current (A)	Max Current (A)
10 Am	0.386	0.334	0.294
11 Am	0.419	0.470	0.450
12 Pm	0.478	0.492	0.445
1 Pm	0.484	0.481	0.476
2 Pm	0.437	0.388	0.446
3 Pm	0.319	0.367	0.362
4 Pm	0.267	0.262	0.266

Figure 5. Time of The day against Max Current in Khartoum state



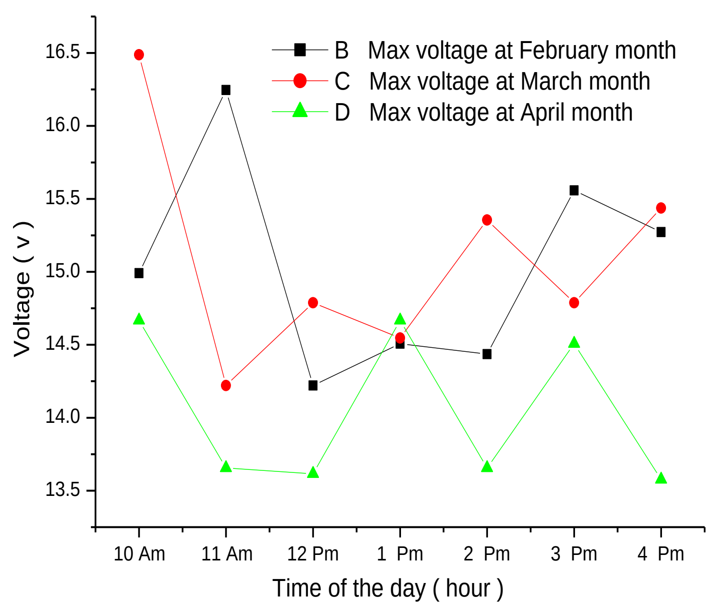
This figure shows the increase and decrease of Current at different months with time of the day.

Table 6 and figure 6 Show the relationship between the time of the day and Max Voltage in Khartoum state at difference months.

Table 6. Time of The day against Max Voltage at different month

Time of the day (hour)	February month	March month	April month
Time	**Max Voltage (V)**	**Max Voltage (V)**	**Max Voltage (V)**
10 Am	14.991	16.488	14.667
11 Am	16.246	14.221	13.655
12 Pm	14.221	14.788	13.616
1 Pm	14.507	14.546	14.667
2 Pm	14.436	15.355	13.655
3 Pm	15.558	14.788	14.507
4 Pm	15.272	15.437	13.577

Table 6. Time of The day against Max Voltage in Khartoum state



This figure shows the random increase and random decrease of Voltage at different months with time of the day.

5. Discussion:

Solar cells output change with solar radiation and temperature changes, both the electrical power output and the efficiency of the solar cell depend on solar radiation and temperature as you have seen in figure (3) and figure (4) respectively.

Solar cell performance decreases with increasing temperature due to recombination and thermalization of the excess energy of photons, the change in solar radiation and temperature will affect the power output from the cells. Max power decreases with increase in module temperature so the efficiency is decreased.

Increase in temperature will decrease the voltage due to voltage factor, the current increase with temperature due to increase in reverse saturation current.

6. Conclusion:

It is important to know the solar radiation and temperature of a solar cell at certain location to predict solar cell performance, it is also important to know the relationship between max power, sun radiation and temperature at different months, the effect of temperature on efficiency of solar cell and its max power, therefore, solar cell must be engineered according to the maximum, minimum and average environmental temperatures at each location.

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