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Conception and Realization of Sun Tracking System in the South-West of Algeria

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Abstract

The objective of this work is to show, in the solar energy converting systems applications as photovoltaic or thermal, the interest of solar tracking system compared to those fixed, south facing and inclined at an optimal angle or a horizontal plane.

Our application is to realize and study the performances of sun tracking system prototype allowing the permanent orientation of the PV module in opposition to incident radiation during the day; hence it permits to increase the output energy and the conversion efficiency

For a state of sky completely or almost clearly, a solar tracking plane enables use to recover an average 27.48% from the gain of energy compared to fixed system; however , our device is able to deliver a maximal power and best conversion efficiency compared with a fixed module oriented by tilt angle 30° identical with the latitude of the site.

Keyswords: Solar area, PV module, Sun tracking, Electronic control

1. Introduction:

Today, the photovoltaic technology represents an important scientific course to exploit the solar energy instead of the fossil energy, for this purpose, the fabrication and the system of using solar panels are directed to generate theirs maximum output powers and conversion efficiency, however, several tasks are examined in order to explore different electrical and thermal parameters influencing as: the solar radiation, the physical factors of module, the operating conditions, azimutal and tilt movements…etc.

In this field, there are grounds for recording the theoretical studies and the experimental works on the solar area and the photovoltaic conversion; as those of M.Iqbal, Duffie and Beckman (1995). For valorizing the energetic gain , we can cite the experimentation of pumping system realized by B.Barkat (Algeria) with a gain from 25% (B. Barakat, 2004), another realization in Egypt by A.A Zekry attained a result of 24% (A.A. Zekry, 2006), a sun

tracking in Japan with a year efficacy from 27%compared with a fix system ,and an automatic system in Spain reached 26% from the gain of energy.

Generally, the performances optimization of PV system is closely linked to increase the efficiency and the produced energy in objective to reduce the cost of the system.

Our purpose in this paper is to study and to measure the incident irradiance and the produced energy from module with tracking mode compared with a fixed system under the operating conditions of site.

The sun tracking system prototype permits the permanent orientation of solar module against to sun during the day, the fixed system is oriented according to a tilt angle in accordance with latitude of site.

The sun tracking has an essential advantage providing the maximum output energy with high accuracy against any variation of incident light from the sun, as it‘s sensible to the climatic conditions change.

The prototype is realized and experienced in “Laboratory of Physics and Semiconductors Devices” (LPDS) in the university of Bechar Algeria.

2. Description of tracking system

The prototype is made of sample tools whose dispose in our research laboratory; and composed by the following elements:

- A solar module.
- A mechanical system pivoted with two motors for rotation.
- An electronic command with devices to the measurement

2.1 Photovoltaic module

The PWX500 is a bi-glass module, perfectly adapted to the climatic and hard environmental conditions, made of 36 polycrystalline cells of silicon; its cells are put in order to serial-parallel grid on total surface at 3672.72 cm^2, the PWX500 module uses the technology of the polycrystalline cells

PHOTOWATT (B. Barakat, 2002), the equivalent circuit used is shown in the figure 1, the relationship between voltage (V) and current (I) for this one-exponential model is given by the following equation (K. Salima, 2002):

$$I = I_{ph} - I_s\left(\exp\left(\frac{q(V + R_{sh} * I)}{\alpha * k_B * T}\right) - 1\right) - \frac{V + R_s * I}{Rsh} \quad (1)$$

Where Rs is the series resistance of the cell (Ω), R_{sh} is the shunt resistance (Ω), α is the ideal factor (usually α=1.2), T is the cell temperature (K) ,q is the electron charge ($1.6021x10^{-19}$ C) ,k_B is the Boltzman’s constant ($1.3854x10^{-23}$ JK^{-1}), I_{ph} is the photo-current (A) and I_s is the saturation current (A)

For extracting a best result, we have based on the technical data specified from the manufacturer as illustrated in the table 1.

2.2 Description of piloting system

The mechanical system is realized by a metallic support for PV module, pivoted with two electrical motors consuming a weak power; controlled by analogical electronic circuit. The radiation is detected by the sensors quadruple (4 photoresistances) against the four geographical sides and measured by the pyranometric probe, then two bearings for rotation (kind 6204) to minimize the friction factor.

The final course switches of motors determinate the limit positions of system shown in fig 2.

This piloting mechanism guides the PV module orientation from the east to the west around a vertical ax with angle (α) and follows the sun from south to north during the seasons of the year according to tilt angle (β) around horizontal ax

The components of the system are chosen according to theirs characteristics in objective to acquire some advantages:

- The consumed power of the system must be more weaken
- The sensors sensibility is accurate for determination the optimal position.
- The resistant couple is proportional to the speed.

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2.3 Orientation and tilt angles of the PV array according to the sun position

The site of Bechar is described geographically by: latitude: 31.38°, longitude: 2.15° w, altitude: 806m, albedo: 0.2, therefore, in our site, the sun is present at 8h05 in winter (21 December) and sets at 19h50 in summer (21 June), so the average solar day is 10 hours which given from [Solar Atlas of Algeria , data collection , national office of university publications] published in 1985 (M.Capderou ,1985).

The tilt of module (β) varies according to two factors: latitude of site and the season of the year according to the following law (F. Chaltin, 2002):

$$\text{Tilt } (\beta) = \text{ latitude of site} - \arcsin\left(0.4 \sin\left(N \cdot \frac{360}{365}\right)\right) \quad (2)$$

N: number of days.

For the fixed mode, PV module is sloped by a tilt angle changed at every month in accordance with the latitude of site toward the geographical south (in our experience the tilt is 30°) and 0° with azimuth angle, but by tracking system the PV module is adjusted automatically at optimal tilt angle according to the sun position sensed by the photoresistances (LDR), and the solar panel is pivoted horizontally with a speed 15°/ h from the east to the west during all the day according to the equations below (A. Chermitti, 2005):

The maximum azimutal angle:

$$\alpha = \frac{180 \; x \;\; average \;\; solar \;\; day\,(hours)}{12} \quad (3)$$

so

$$\alpha = \frac{180x10}{12} = 150°$$

The rotation speed is:

$$\omega = \frac{\max imum \;\; azimutal \;\; angle}{average \;\; solar \;\; day\,(hours)} \quad (4)$$

then

$$\omega = \frac{150°}{10} = 15 \;\; \deg re / hour$$

In objective to measure the irradiation change after every 20 min the angle of the LDR sensor can be calculated from the formula: $\delta = t\,x\omega = 0.33x15 = 5°$ where this angle is symbolized in the figure 3

2.4 Electronic circuit for control:

The electronic circuit to power on and to control the system is schematized in fig (05):

The base element of this electronic circuit is the comparator LM324 which detects the difference of voltages between its reverser input and no reverser input produced from the difference of illumination on the surface of the sensors LDR1and LDR2, at this moment, LM 324 provides a signal to the power amplifier of transistors T_1=T_3=BDWX93C on commutation with T_2=T_4=BDWX94C for turning motor (M) until the PV module is trained to positioning face the sun as the light is identical on the sensors like initial stage , the diode bridge D1=D_2=D_3=D_4=1N4001 is used for protecting the motor against voltages displaying during its movement, the second motor is feed with another similar circuit functioning by the same principle (G.E. Ahmad, 2004).

3. Results and discussion

The experimentation was applied with two methods:

- Fixing PV module with a tilt angle 30° toward geographical south.

- Moving the PV module with the tracking system whose the tilt angle and the azimuth angle vary simultaneously according to the movement of the sun.

The measurement was taken under an average temperature of 27° C, and the speed of wind was very weak 2.60 m/s given from the Algerian weather house in Bechar, in these conditions, we investigated to obtain two results:

- Current – voltage characteristics and power- voltage characteristics for the two orientation modes.

- Optimization of the produced power of module using the tracking system.

3.1 First case

The comparison between these two modes of orientation, for extracting the performances of each mode it can be determinated in the table 2:

In the fixed mode, at the 8h30, the maximum produced power (8.12 w) is very inferior than the nominal power of the PV module designed by the manufacturer (50 W), in spite of the ambient temperature is agreeable and under 236.5 w/ m² of irradiation, thus explains that the insufficiency of solar irradiation on the surface of the sensor, in other meaning, the fixed position can't hold a great quantity of irradiation because the PV module surface is not perpendicular toward the sun at each time.

At the same time in the morning, the sun tracking system allows to hold a double flow of irradiation (790.02 w /m²), therefore the produced power grows up to 34.56 w with the efficiency 11.92 %, and obtained a gain of 27.48 %, show the I-V and the P- V characteristics curves in figure (6) and (7).

According to the analysis of the solar panel's performances, we can conclude that:

- The influence of the orientation and the inclination angles is important; the fixed panel can not deliver the maximum of electrical energy.

- The I-V and the P-V characteristics of the solar panel turning around two axes, illustrate the improvement of the maximum power and the efficiency of the conversion at 11.92% compared with the fix panel.

3.2 Second case

At the time 12h30, the fixed PV module obtained an important energy (34.98 w) while the irradiation increased until 956 w/m² and was vertical on its surface, however the sun tracking system put out 38.61 w under illumination 958 w/ m², in this case the irradiation is vertical on the PV module surface in the two modes, there is no difference between them, over that, the efficiency and the gain are very approached, in consequence their current –voltage and power characteristics are identical in figures (8) and (9).

3.3 Third case

In the evening, at 17 h20, the fixed PV module decreases its output energy at 10.22 w according to the decreasing of the irradiation on the surface (293.5 w / m²), otherwise the sun tracking system kept its production 36.65 w with 848.5 w / m², in this case the divergence is similar to the characteristics curves in the morning, the current-voltage and power characteristics are shown in the figures(10)and (11).

According to the results of the last figures, we concluded that the tracking system of that panel allows optimizing the maximum power compared with the fixed mode.

We can deduct the variation of the instantaneous efficiency by function of the radiation according to the relation:

$$n = \frac{V \cdot I}{S \cdot E} = \frac{P_{max}}{S \cdot E} \quad (5)$$

with S=0.367 m^2

S: surface of the module, E: incidental radiation

According to the analysis of the panel's performances, we can summarize that:

- The panel movement permits to increase the quantity of the incidental energy on the surface of the panel and also the power delivered by the sensor.

- The P(V) characteristic of panel turning around two axes, indicates the perfection of the maximal power converted ,as well as the efficiency is elevated until 11.76% under a radiation of 848.5 w/m^2, it is due to the influence of the variable orientation angle.

The gap of the radiation between two modes gets at 553.52w/m^2 compared with fix mode oriented by 30° toward the south.

The test of the panel at the end of the day permitted us to raise the I-V characteristic illustrated on the figure 10, that indicates an important change of the values in the current and in the voltage compared with fixed mode, at functioning peak (14.9 v, 2.46 A).

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The P-V characteristics on figure 11 of the panel pivoted following two axes , specifies that under the radiation of 848.5 w/m^2 and an ambient temperature of 27° , the maximal power gets at 36.65 w , more that the fixed panel ,the voltage of the opened circuit arrives at 20.6 v and the current of the short circuit reached 3.09 A .The radiation on the surface of the panel in tracking mode is bigger than the fixed mode at the beginning and the end of the day , other wise at the mid-day interval , the gap of the radiation is weak and the gain in energy is not considerable for two axes.

The gain in energy of tracking system gets at 27.48 % compared with fixed mode that presents the concordance with the results of gain [24 % to 27 %] published by studies very recent (K. Salima, 2002).

The figure 12 presents the characteristics of measure of the power converted by the PV module in three different periods of the day. These 03 graphs are nearly confounded. From that we can conclude that the experimentation of tracking system proved a daily efficacy of about 1.5 once more that the fixed system's oriented to 30° towards the south. But the characteristics of the figure 13 are especially different that of 12h30 which is near in comparison at that panel in tracking mode .the maximal power converted in tracking mode follows the variation of the solar radiation (as is indicated in the table N°03) and in consequence the improvement of the efficiency of the conversion.

4. Conclusion

The obtained results explain that the sun tracking system can deliver a maximal power and best conversion efficiency compared with a fixed panel under the climatic and geographical conditions of the site.

The comparison between the orientation's modes proves that the tracking system is characterized by the following advantages:

- The inclination and the orientation are variables simultaneously according to the movement of the sun at each time.

- The radiation received by the panel is important than the radiation in fixed mode and the production of the power is maximal according to the incidental radiation.

- The tracking system has a great importance especially in the morning and at the end of the day where the tilt angle of the fixed system is very far from the optimal position of sensor; and the gain in daily energy is very important in order of 28%.

- The panel is piloted automatically with a grand accuracy if the tracking system becomes more performant.

- The system can be made use of cooling device to maintain the temperature appropriate to panel cells.

We can conclude that the fixed solar module is unlack to generating the maximum power at each time, so it necessary to pivot it by tracking system for optimizing its performances.

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Table 1. PV module's characteristics under the standard conditions

Electrical and thermal characteristics	**Unit**	**Standard Values**
Nominal power	W	50
Nominal voltage	V	17.2
Nominal current	A	2.9
Short-circuit current	A	3.1
Open circuit voltage	V	21.6
efficiency	%	12.19
weight	Kg	9.2
Current temperature coefficient	A/°C	$1.3x10^{-3}$
Voltage temperature coefficient	V/°C	$-72.5x10^{-3}$
Noct	% /°C	0.43
Serial resistance	Ω	0.55
Number of Cells		36
Surface of cell	cm²	102.02
Standard Conditions		1000 W/m²,25°C, 1m/s

Table 2. Results and Performances for Orientations modes (obtained on 03/04/2008)

Orientation mode	Parameters (optimal value)	8h30	12h15	17h20
Fixed mode	Irradiation (W/ m²)	236.5	956	293.5
	Voltage (V)	14.5	14.7	14.4
	Current (A)	0.56	2.38	0.71
	Power (W)	8.12	34.98	10.22
	Efficiency %	9.35	9.97	09.48
Tracking mode	Irradiation (W/ m²)	790.02	958	848.5
	Voltage (V)	15.5	14.3	14.9
	Current (A)	2.23	2.7	2.46
	Power (W)	34.56	38.61	36.65
	Efficiency: n (%)	11.92	10.98	11.76
	$gain = \frac{n - n_0}{n_0}$ (%)	27.48	10.13	24.05

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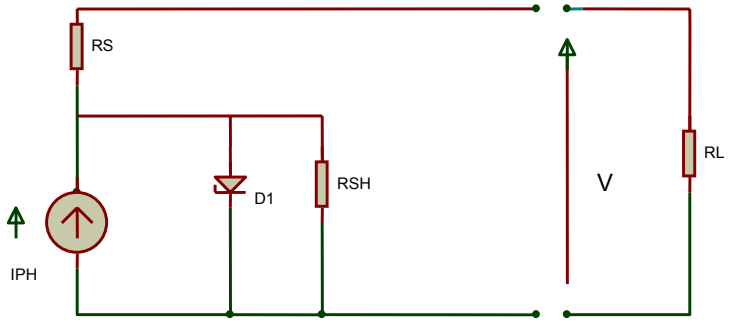

Figure 1. The equivalent electric circuit of the solar panel

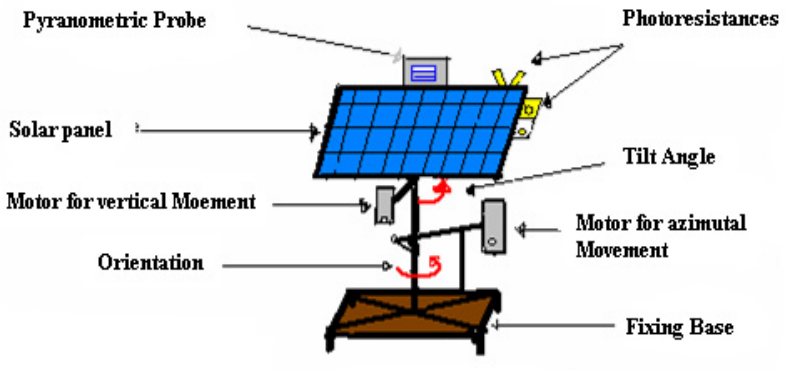

Figure2: Sun Tracking System

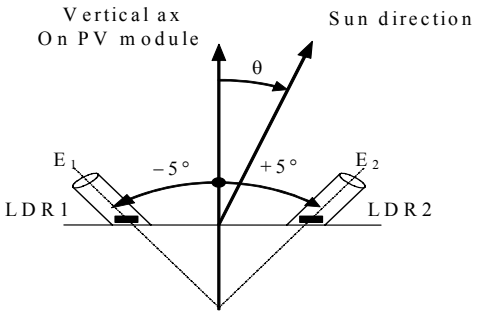

Figure 3. LDR sensors position

Figure 4. Realized sun tracking system

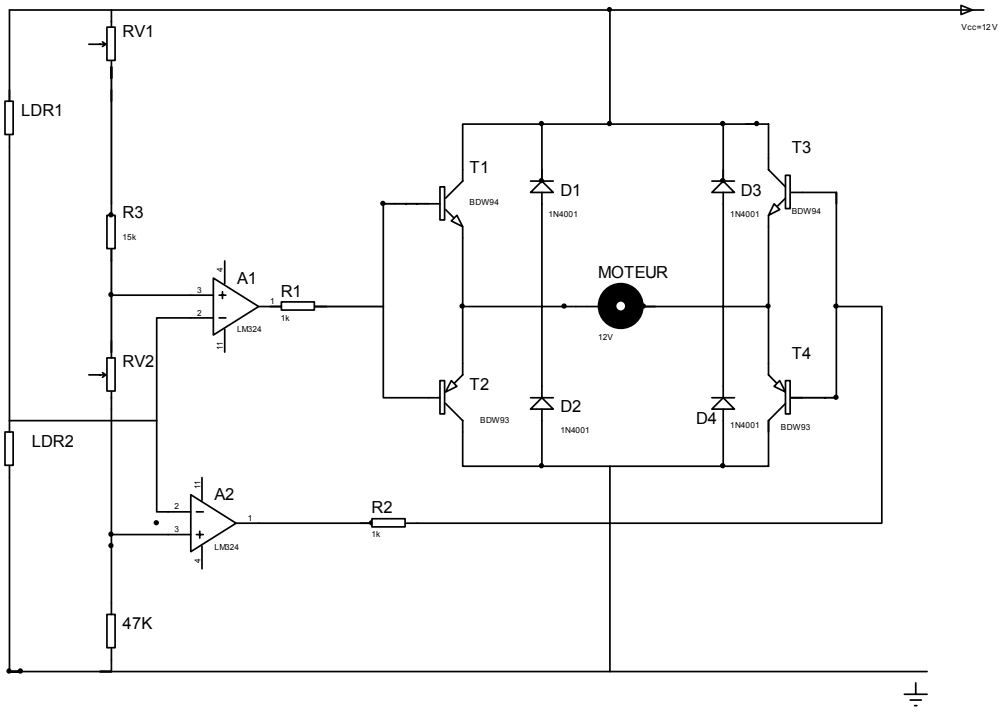

Figure 5. Electronic circuit for system

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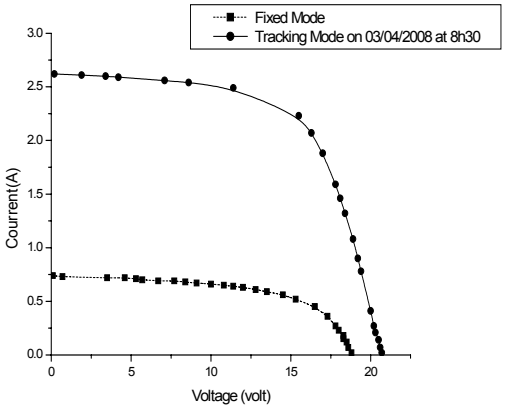

Figure 6. I-V characteristics at 8h30

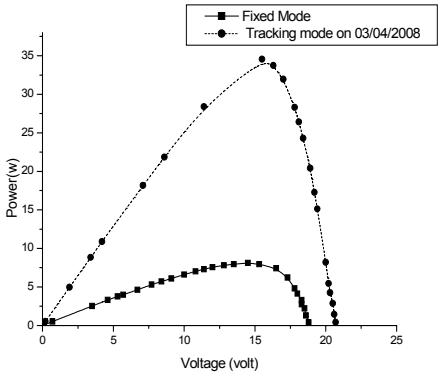

Figure 7. P-V characteristics at 8h30

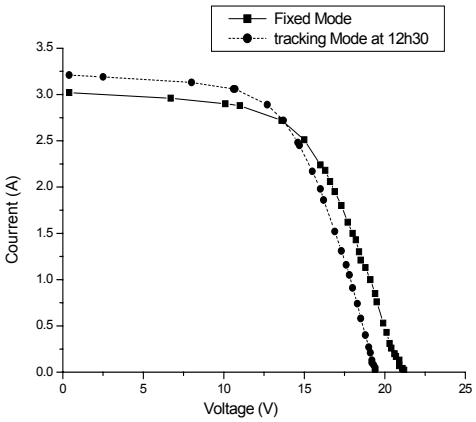

Figure 8. I-V characteristics at 12h30

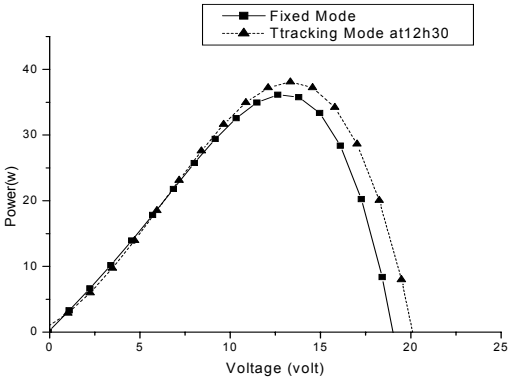

Figure 9. P-V characteristics at 12h30

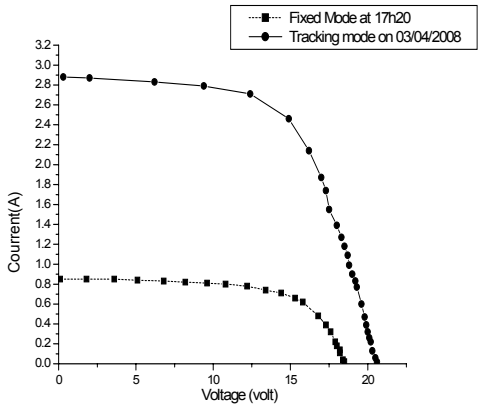

Figure 10. I-V Characteristics at 17h20

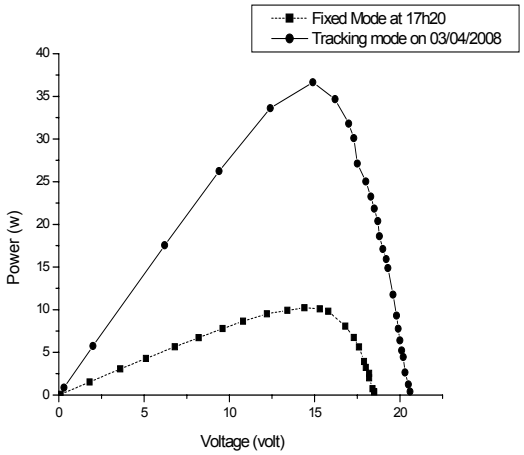

Figure 11. P-V characteristics at 17h20

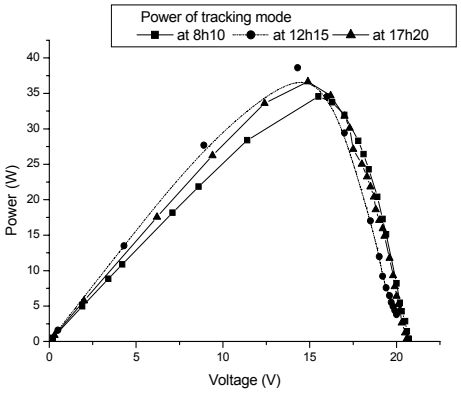

Figure 12. P-V characteristics of panel in tracking mode

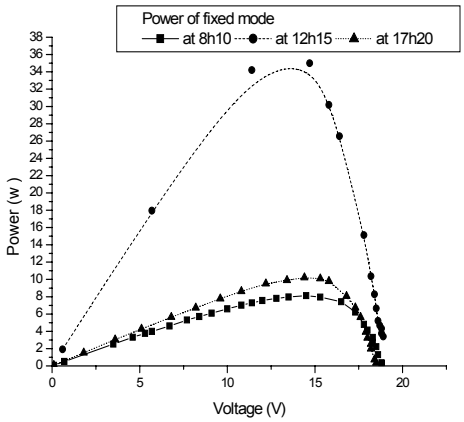

Figure 13. P-V characteristics of fixed mode