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Annual Performance of Solar Modules with Tilting Angle Facing South and Sun Tracking in Tanta, Egypt

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Abstract-In this study, the performances of three modules have been determined. The measured data of the three photovoltaic modules (50W,100W and 17W), such as their open circuit voltage(V_{oc}),short circuit current (I_{sc}), ambient temperature (T_{amb}) , module average temperature(Tm_{av}) and global solar radiation on horizontal surfaces have been investigated for studying of the performance of these solar modules. These measurements have been carried out at the top of the Faculty of Science, Tanta University, of Latitude ($30^{o}41'$) and longitude of (30 99) during the period (March 2008–February 2009). The module efficiency (η_m), Fill Factor (FF), series resistance (R_s) and shunt resistance (R_p) for these modules have been calculated. Also, the hourly solar radiation values (I_t) on the three modules with tilting angle 30.68^o facing south have been calculated from the measured global solar radiation on horizontal surfaces. Good performance results have been obtained for the position of sun tracking rather than facing south in most cases.

Keywords: Annual performance, efficiency, photovoltaic modules, fill factor, shunt resistance, series resistance, tilting angle, sun tracking, and facing south.

1. Introduction

The need for an increasing use of photovoltaic energy systems is acknowledged throughout the world [1]. The global installed capacity of photovoltaic systems in 2003 grew to 1809 MW [2]. Approximately 48% of the total, or 860 MW, was installed in Japan. More than 80% of this capacity was installed in residential photovoltaic systems. Germany, however, had taken the lead in residential use of photovoltaics with the initiation of the 1000 roof program in the early 1990s. Furthermore, in 1999, the German government implemented another program to encourage the installation of 100,000 roofs by 2004. Global photovoltaic module shipments grew to about 744 MW in 2003, an increase of 32.5% compared with the preceding year [2]. Japan produced 364 MW, or almost one –half of global photovoltaic module shipments. Also, Japan set a domestic installation of photovoltaic-power generation systems of capacity 4.82 GW by 2010.

This high growth rate has led to an increase in research projects on various aspects of photovoltaics, from the development of novel photovoltaics cells [4, 5] to the performance analysis, sizing, performance estimation and optimization of PV energy systems [6-10]. As well as the characteristic parameters, the performance of a PV module is dependent on the climatic conditions of the location of study. The technical data provided by the manufacturers may not necessarily describe the performance of PV modules at a particular site because the climatic conditions can differ dramatically from the Standard Test-Conditions (STC). This may lead to over or under estimation of energy production in real working conditions. Indeed an overestimation of the production by up to 40% was reported in comparison to the production in STC [11]. Therefore, the knowledge of important characteristics of PV modules under real conditions is of great importance performance for determining their

The geometric factor influences the availability of solar energy. The distance between the sun and the earth varies depending on the day of the year, thus the value of the collected energy to the user also varies with the time of year [12]. Cloud, aerosols and atmospheric gases also contribute in attenuating the incoming solar irradiance by both scattering and absorption processes [13]. Also, there is an important factor affects the photovoltaic module output power. This is the type of module mounting because it changes the amount of incident solar radiation on the module.

Terrestrial application of photovoltaics (PV) is developing very slowly. Nevertheless, PV fascinates not only the researchers, but also the general public. Its strong points are: direct conversion of solar radiation into electricity, no mechanical moving parts, no noise, no high temperatures, no pollution, a long lifetime. PV is a flexible energy source; its power is ranging from microwatts to megawatts [14]. **T**he aim of this study is to calculate the performance of three photovoltaic solar modules (50W silicon monocrystalline, 100W silicon monocrystalline and 17W Triple junction silicon solar cells (Amorphous solar module)) facing south/and sun tracking, with tilting angle 30^o, from horizontal installed at the top of the faculty of Science/Tanta University (latitude $30^o 41'$ and longitude 30 99), Egypt under real conditions.

2. Instrumentations

2.1.Measurements of the global solar radiation

In this work, the instrument which we have used for global solar radiation measurements is the Eppley-Precision Spectral Pyranometer (E-PSP). The (E-PSP) is connected to an instantaneous solar radiation meter (model No. 455). This meter is usually scaled to the sensitivity of a particular radiometer to read out directly in the standard international units of watt per square meter.

2.2. Commercial PV modules technical information

Single-crystalline silicon photovoltaic (50W) module

The photovoltaic module under study is made up of 36 cells connected in series, each cell has square shape with physical dimensions 10.4cm×10.4cm , adding up to a total area of 0.389376 m^2. The manufacturer’s module specifications are listed in Table 1, together with the baseline measurements that are used as reference.

Table 1. Electrical characteristics rated by the manufacturer at standard test conditions (1000W/m^2 irradiance, 25^{o}C cell temperature and air-mass 1.5 global spectrum)

Performance parameter	Manufacturer	unit
Maximum power (P_R)	50	Watts
Short-circuit current (I_{sc})	3.32	A
Open-circuit voltage (V_{oc})	20.9	Volt
Voltage at a maximum power (V_R)	16.67	Volt
Current at a maximum power (I_R)	3.0	A
Nominal operating cell temperature	43	^{o}C

Voltage variation vs temperature	-90	mv/°C

Amorphous silicon photovoltaic solar module (17W)

Triple junction silicon solar cells (Amorphous solar module) 17W (UNI- solar, Solar electric shingle, United solar system corp. Troy, M1) and Model type: SHR-17 which comprises 12 solar cells connected in series. Each cell has a rectangle shape with physical dimensions 19cm×12cm, adding up to a total area of 0.2736 m^2. The manufacturer's module specifications are listed in Table 2 together with the baseline measurements that are used as reference.

Table 2. Electrical characteristics rated by the manufacturer at standard test conditions (STC: 1000W/m2 irradiance, 25°C cell temperature and air-mass 1.5 global spectrum).

Performance parameter	Manufacturer	
Maximum power (P_R)	17.3	Watts
Short-circuit current (I_{sc})	2.52	A
Open-circuit voltage (V_{oc})	12.0	Volt
Voltage at a maximum power (V_R)	8.60	Volt
Current at a maximum power (I_R)	2.01	A
Maximum system voltage	60	VDC
Series fuse	4.0	A
Min. Blocking/Bypass Diode	4.0	A

Single-crystalline silicon photovoltaic (100W) module

The photovoltaic module under study is made up of 36 cells connected in series, each cell has square shape with physical dimensions 13.5 cm×13.5 cm, adding up to a total area of 0.6561m^2. The manufacturer's module specifications are listed in Table 3 together with the baseline measurements that are used as reference.

Table 3. Electrical characteristics rated by the manufacturer at standard test conditions (STC: 1000W/m^2 irradiance, 25°C cell temperature and air-mass 1.5 global spectrum).

Performance parameter	Manufact -urer	Unit
Maximum power (P_R)	90-100	Watts
Short-circuit current (I_{sc})	6.2	A
Open-circuit voltage (V_{oc})	20.7	Volt
Voltage at a maximum power (V_R)	16.7	Volt
Current at a maximum power (I_R)	5.4	A
Nominal operating cell temperature	43±2	°C
Voltage variation vs temperature	-90	mv/°C
Wind loading or surface pressure	2400	N/m^2
Storage and operative temperature	-40 to +95	°C
Typical current at battery operating voltage (12.5V)	5.4	A

3. Methods of Investigation

The studies of the electrical performance of the photovoltaic solar modules have been done with the aid of sun tracking and face south conditions to investigate the characteristic curves of the 50W, 17W and 100W PV modules – at outdoor conditions - around a whole year from March 2008 to February 2009. The current–voltage and power–voltage characteristics have been measured. The three modules have been mounted with tilting angle (30^0), which is equal to the latitude of the location. The modules are installed on top of the Faculty of Science at Tanta University, Tanta Egypt. The first outdoor exposure tests have been started on 2008, March 16^{th} and continuously for one year long, facing south /and Sun tracking. The experiment has been performed three times a day for 6 days every month for a one year. For every module, we have selected the data of the average month for each season such as January, April, July and October for both sun tracking and face south measurements.

3.1 Computer programming for PV solar modules electrical characteristics

For calculating the PV characteristics, series resistances R_s, shunt resistances R_p, fill factors and efficiencies for the position facing south of the 50W , 17W and 100W modules, a computer program has been prepared by using equations (1-5), The input parameters to the program are climatic, design and operational parameters. Also the following equations are used to calculate the fill factor and efficiency of the three modules [15, 16]:

$$FF = \frac{V_R I_R}{V_{oc} I_{sc}} \tag{1}$$

$$\eta_m = \frac{P_R}{A_m \times P_{in}} = \frac{FF \times V_{oc} \times I_{sc}}{A_m \times P_{in}} \tag{2}$$

Where, P_{in} is the solar irradiance and A_m of the solar module.

Eq. (3) and (4) give the thermal voltage V_t and the series resistance R_s, respectively [17], while Eq. (5) gives the shunt resistance R_p [18][19].

$$V_t = \frac{kTm_{av}}{q} \tag{3}$$

Where Tm_{av} is the module temperature (K), q is magnitude of the electron charge and k is Boltzmann constant.

$$R_S = \frac{V_R}{I_R} \frac{\left(\frac{1}{V_t}\right) \times (I_{sc} - I_R) \times \left[V_{oc} + V_t Ln\left(1 - \frac{I_R}{I_{sc}}\right)\right] - I_R}{\left(\frac{1}{V_t}\right) \times (I_{sc} - I_R) \times \left[V_{oc} + V_t Ln\left(1 - \frac{I_R}{I_{sc}}\right)\right] + I_R} \tag{4}$$

Where V_R is the module voltage at the maximum power point, and I_R is the module current at the maximum-power point.

$$R_p = \frac{(V_R - A \times V_t) \times (V_R - I_R \times R_S)}{(V_R - I_R \times R_S) \times (I_{sc} - I_R) - (I_R \times A \times V_t)} \tag{5}$$

where A is the ‘‘ideality factor’’ which is considered as unity.

3.2 Current – Voltage measurements set up.

Current -voltage of the solar PV modules is measured using a schematic diagram shown in Fig.1. A digital Multimeter DT9205A, Multimeter Fluke73 and Multimeter DT92205N were used for both I and V for the PV modules. A variable load resistance about ≈ 11.3165 KΩ was designed and used during measurements, which is divided into three resistances R_1, R_2 and R_3.

(I) Resistance R_1 equals 29.241Ω. It is a wire made of Nickel Chrome which has diameter and length equal 0.11cm and 17.10m, respectively.

(II) Resistance R_2 equals 177.3Ω. It is a wire made of Nickel Chrome which has diameter and length equal 0.08 cm and 50.40 m, respectively.

(III) Resistance R_3 equals 11.110 KΩ, H.TINSLEY& CO.LTD LONDON S.E.25, and Type (5274-4D). Fig.1 shows the schematic diagram of the Current voltage measurements of the PV solar modules.

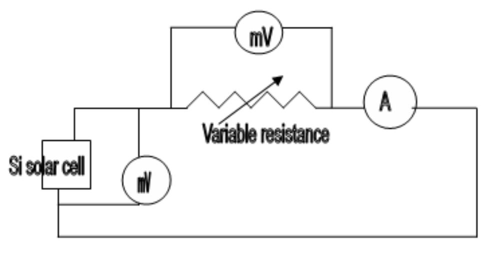


Fig. 1. Schematic diagram of the current- voltage curves of PV solar modules

4. Results and discussion

4.1 Sun tracking and facing south PV characteristics curves for the single-crystalline silicon photovoltaic (50W) module

Figures 2, 4, 6 and 8 show current-voltage characteristic curves and Figures 3, 5, 7 and 9 show power-voltage characteristic curves in winter, spring, summer and Autumn for both positions of sun tracking and facing south have been done for (50W) module. It is clear that in winter, at the first period the position of facing south is having a better value than sun tracking, the maximum power values for them are 23.51 and 23.07 W, respectively. At solar noon, the second period, the position of sun tracking is having a better value than the position of facing south; the maximum power values for them are 29.62 and 17.49 W, respectively. At the third period the position of sun tracking is having a better value than of facing south, the maximum power values for them are equal 18.9 and 14.6W, respectively.

In Spring, for three periods on the day the position of sun tracking is having a better value than the position of facing south, the maximum power values for the positions of sun tracking and facing south are 23.3and 22.89W for the first period and for the second period are 25.37 and 23.02W and for the third period are 20.4 and 18.07W, respectively.

In summer, for two periods on the day, the position of sun tracking is having better values than of facing south. For the first period; the maximum power values for the positions of sun tracking and facing south are 22.83 and 19.26W, while for the third period are equal 23.27 and 21.78W but for the second period; it has been found that the position of facing south is having a better value than of sun tracking. The maximum power value for the positions of sun tracking and facing south are 22.95 and 26.13W, respectively.

In autumn, for the three periods on the day, the position of sun tracking is having better values than facing south. The maximum power values for the position of sun tracking and facing south are 26.5and 23.44W for the first period and for the second period are 25.08 and 24.99W while for the third period are 19.4 and 12.42W, respectively.

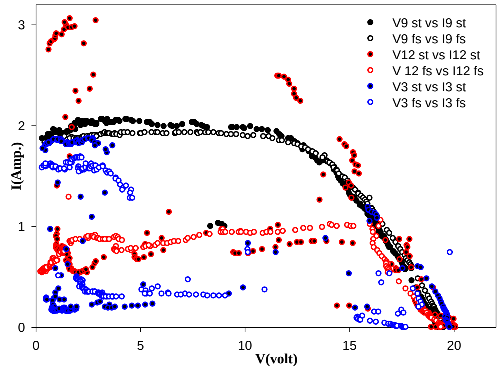


Fig. 2. I-V characteristic curves for the (50W) module in Winter for the positions of sun tracking 17/1/2009 and facing south 18/ 1/ 2009.

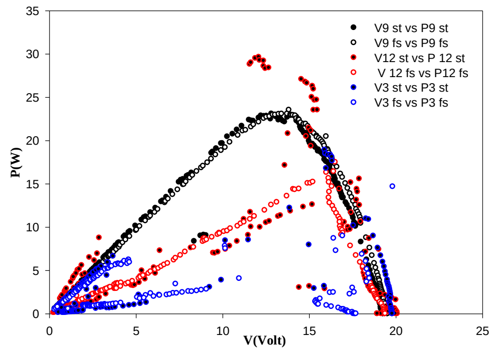


Fig. 3. P-V characteristic curves in Winter for sun tracking 17/1/2009 and facing south 18/ 1/ 2009.

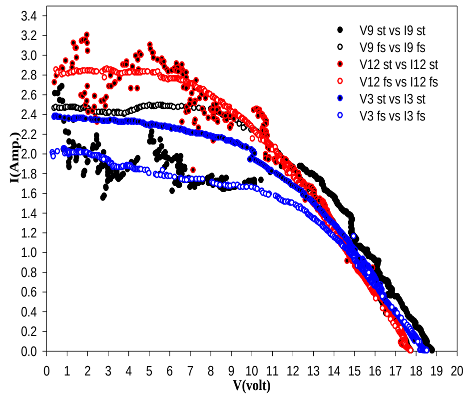


Fig. 4. I-V characteristic curves for the (50W) module in spring for the positions of sun tracking 18/4/2008 and facing south 19/4/ 2008.

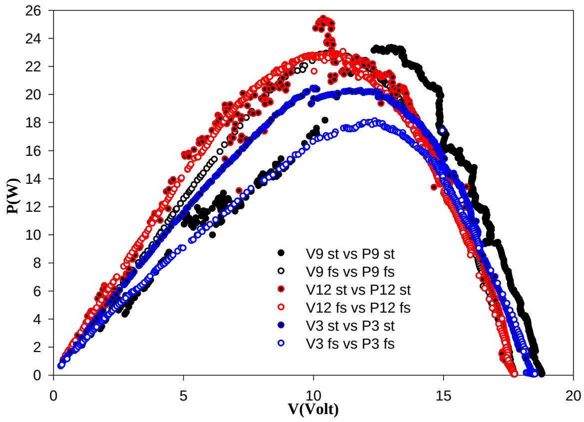


Fig. 5. P-V characteristic curves for the (50W) module in Spring for the positions of sun tracking 18/4/2008 and facing south 19/4/2008.

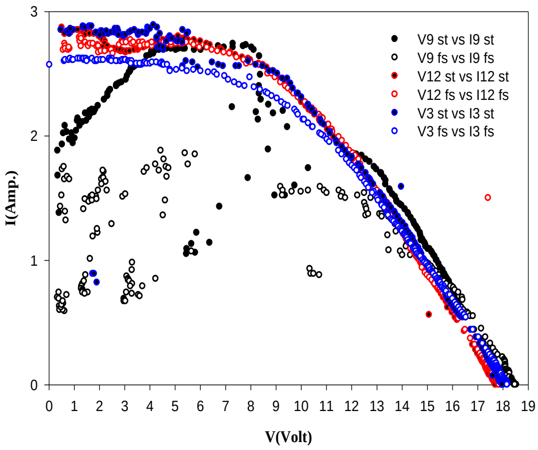


Fig. 6. I-V characteristic curves for the (50W) module in Summer for the positions of sun tracking 21/ 7/ 2008 and facing south 22/ 7/2008.

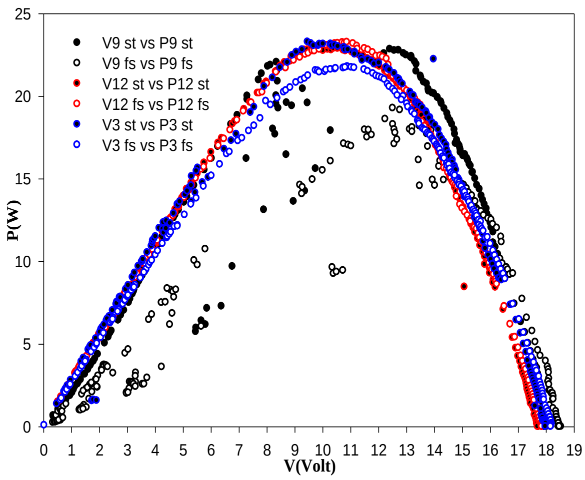


Fig. 7. P-V characteristic curves for the (50W) module in summer for the positions of sun tracking 21/ 7/ 2008 and facing south 22/7/ 2008.

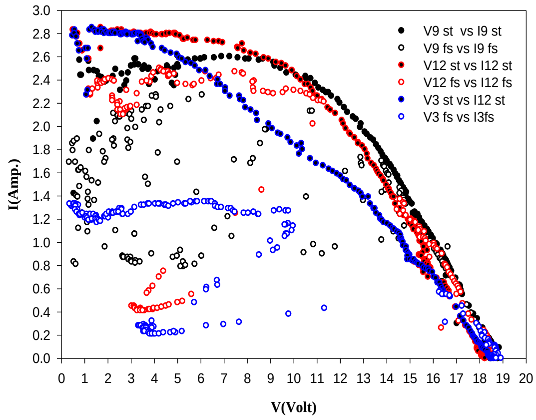


Fig. 8. I-V characteristic curves for the (50W) module in autumn for the positions of sun tracking 15/10/ 2008 and facing south 16/10/ 2008.

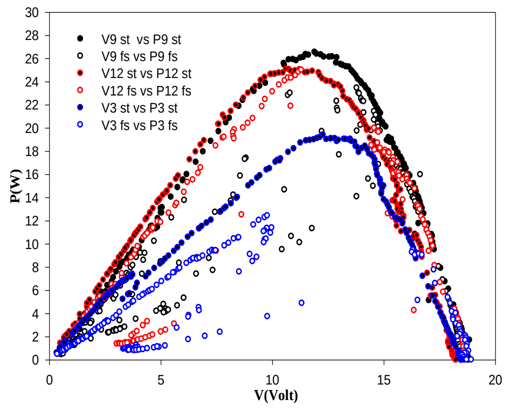


Fig. 9. P-V characteristic curves for the (50W) module in autumn for the positions of sun tracking 15/10/ 2008 and facing south 16/10/ 2008.

Table 4 shows the calculated results for the (50W) module at solar noon for summer (July), autumn (October), winter (January) and spring (April) for the position of facing south with tilting angle 30^o. The incident radiations on the (50W) module have been found as follows: 921.38, 547.87, 247.7 and 850.17 Wm^{-2}, respectively. Also the maximum power values have been found to be 26.13, 22.5, 8.7 and 22.99W, respectively. It has been found that the best efficiencies have been obtained in winter and autumn while the smallest efficiencies are in summer and spring. The input power values have been obtained as follows: 358.84, 213.33, 96.45 and 331.04W, respectively. For this module, it has been found that the temperature is an important parameter, which has high effect in summer and nearly little effect in winter. The maximum power and the minimum power have been achieved in summer and in winter, respectively. Also from the results of Table 4, it is evident that large values of R_S decreased the short circuit current values to become smaller, while small values of R_p reduced the voltage. The maximum and the minimum FF have been achieved in summer and in winter, respectively.

Table 4. Computing values for the PV solar module (50W) at solar noon by using computer programming-Pascal language.

PVM-50W	Tm_{av}	I_{sc}	V_{oc}	I_R	V_R	FF(%)	R_s	R_p	η_m(%)
Winter	332	1.29	19.39	0.5	17.4	35	34.73	49.67	9.02
Spring	343.5	2.86	17.76	2.1	11	45	5.21	74.66	6.94
Summer	347	2.8	17.87	2.4	10.8	52	4.37	169.62	7.28
Autumn	340	2.5	18.67	2	11.3	48	5.55	134.31	10.55

4.2 Sun tracking and facing south PV characteristics curves for the amorphous silicon (17W) module.

Figures 10, 12, 14 and 16 explain I-V characteristic curves. Figures 11, 13, 15 and 17 present P-V characteristic curves in winter, spring, summer and autumn for both positions of sun tracking and facing south have been done for the module (17 W).

It is clear that in winter, for the three periods on the day, the position of sun tracking has better values than of facing south. For the positions sun tracking and facing south, the maximum power values obtained were 9.26 and 8.74W for the first period and for the second period were 11.25 and 10.92 W while for the third period were 6.87 and 6.64W, respectively.

In spring, for the second and third periods on the day, the position of sun tracking have better values than facing south. The maximum power values for the position of sun tracking and facing south have been found to be 9.2092 and 8.73 W for the second period and for the third period are 8.7454 and 5.89W, respectively. For the first period; it has been found that the position of facing south has better value than sun tracking. The maximum power values for the position of sun tracking and facing south are 9.0298 and 9.9129W, respectively.

In summer, for the first and third periods on the day the position of sun tracking have better values than facing south. For 9:00 AM period; the maximum power values for the position of sun tracking and facing south are 9.66 and 7.93W and for the third period are 9.4804 and 8.9790W, respectively. while for the second period; it has been found that the position of facing south has better value than of sun tracking, the maximum power values for the position of sun tracking and facing south are 9.3939and 9.6025W, respectively.

In autumn, for the three periods on the day the position of facing south has a better value than sun tracking. The maximum power values for the position of sun tracking and facing south are 8.5302and 9.6696W for the first period, for the second period are 8.4588 and 9.2224W and for the third period are 2.1465and 4.59W, respectively.

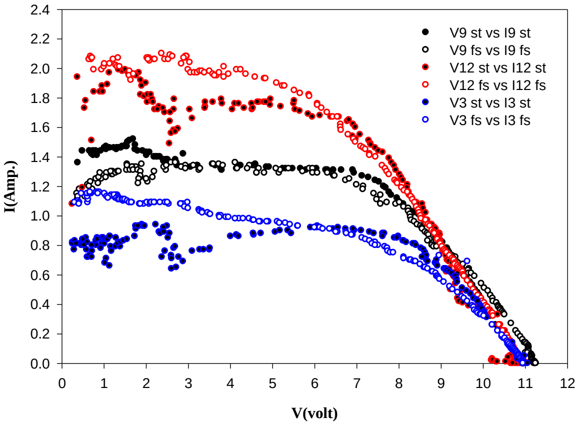


Fig. 10. I-V characteristic curves for the (17W) module in Winter for the positions of sun tracking 20 /1/ 2009 and facing south 21/ 1/ 2009.

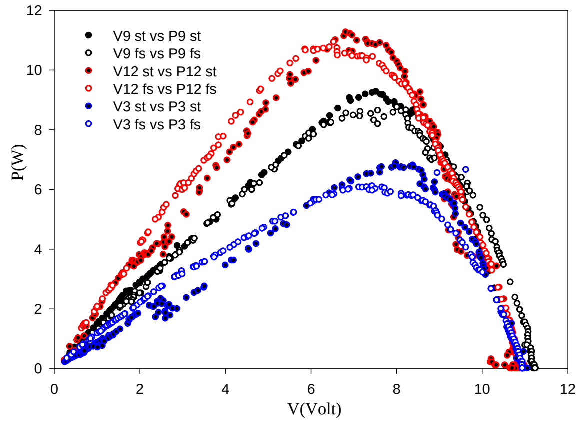


Fig. 11. P-V characteristic curve for the (17W) module in Winter for the positions of sun tracking 20 /1/ 2009 and facing south 21/ 1/ 2009.

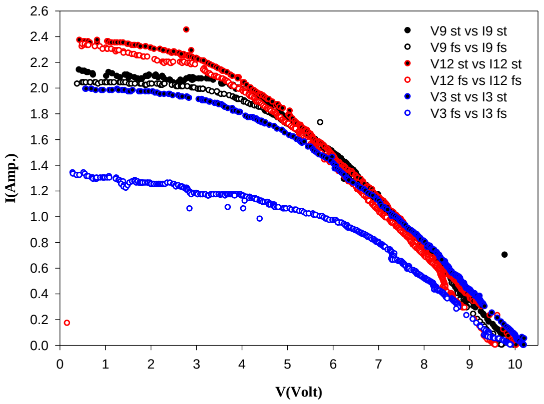


Fig.12. I-V characteristic curves for the (17W) module in Spring for the positions of sun tracking 22 /4/ 2008 and facing south 23/ 4/ 2008.

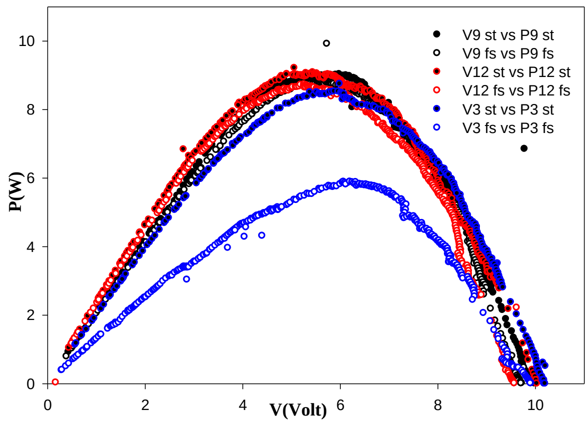
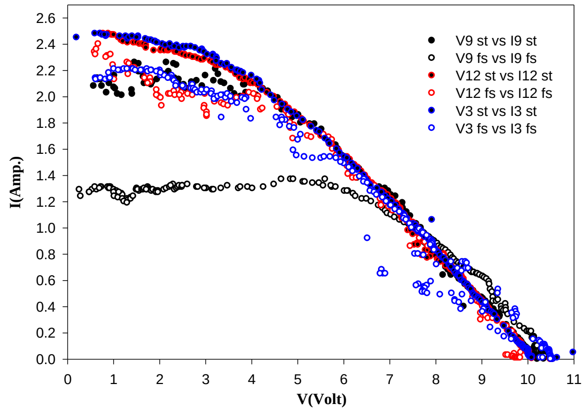


Fig. 13. P-V characteristic curves for the (17W) module in Spring for sun tracking 22 /4/ 2008 and facing south 23/ 4/ 2008.



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g. 14. I-V characteristic curves for the (17W) module in Summer for the positions of sun tracking 23 /7/ 2008 and facing south 24/ 7/ 2008.

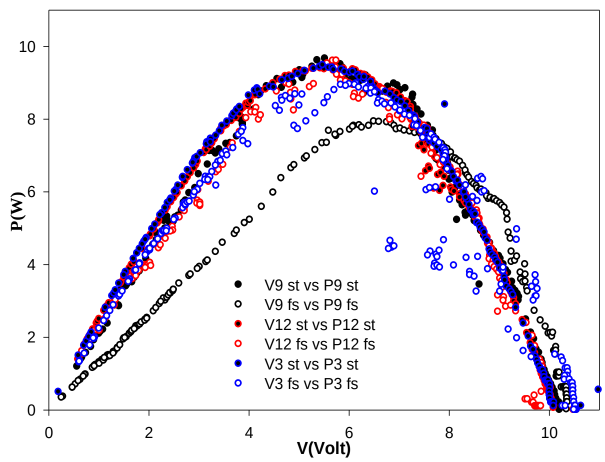

Fig. 15. P-V characteristic curves for the (17W) module in Summer for the positions of sun tracking 23 /7/ 2008 and facing south 24/ 7/2008

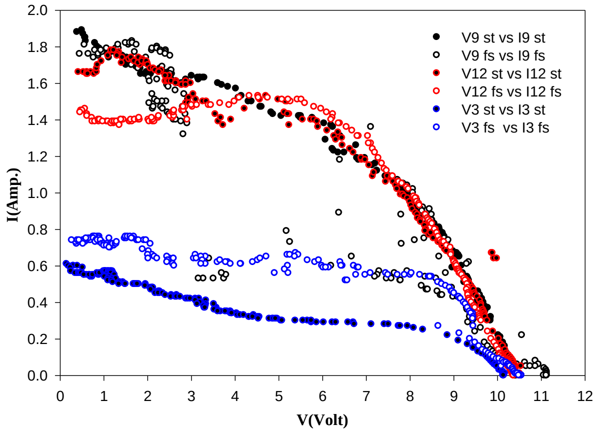

Fig. 16: I-V characteristic curves for the (17W) module in Autumn for the positions of sun tracking 17 /10/ 2008 and facing south 18/ 10/ 2008.

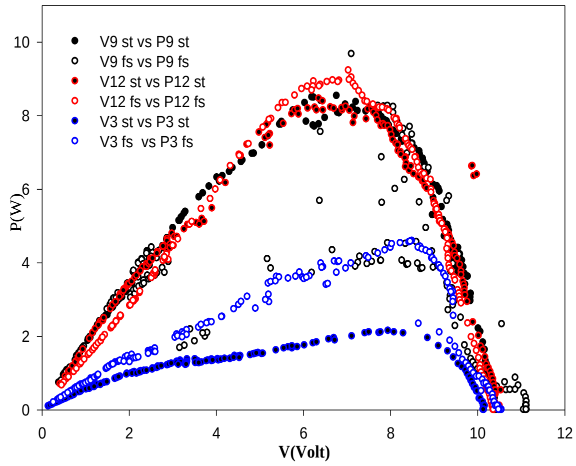

Fig. 17: P-V characteristic curves for the (17W) module in Autumn for the positions of sun tracking 17 /10/ 2008 and facing south 18/ 10/ 2008.

Table 5 shows the calculated results for the (17W) module at solar noon for summer (July), autumn (October), winter (January) and spring (April) for the position of facing south with tilting angle 30^o. The incident radiations on the (50W) module have been found as follows: 834.07, 686.01, 952.88 and 897Wm^{-2}, respectively. The input power values have been obtained as follows: 232.46, 191.19, 265.57and 250.2200W, respectively. Also the maximum power values have been found as 9.60, 9.22, 10.92 and 8.7W respectively. It is found that the best efficiencies have been achieved in summer and autumn and the least efficiencies are in winter and spring.

From the results of Table 5, it is evident that large values of R_S decreased the short circuit current values to become smaller, while small values of R_p reduced the voltage. For the two (50W) and (17W) modules it has been found that the most of time, the position of sun tracking has better value than of facing south for the three modules, but we cannot expect the conditions of the weather for any day because it is varying from hour to hour.

Table 5. Computed values of the electrical parameters for PV Triple junction solar module (17W) at solar noon:-

PVM-17W	Tm_{av}	I_{sc}	V_{oc}	I_R	V_R	FF(%)	R_s	R_p	η_m(%)
Winter	331	2.1	10.9	1.6	6.6	47	3.92	88.05	4.1
Spring	342	2.34	9.62	1.7	5.3	39	3.11	95.77	3.49
Summer	345	2.4	10.5	1.7	5.7	38	3.34	110.6	4.13
Autumn	340	1.53	10.38	1.3	7	58	5.13	131	4.82

4.3 Sun tracking and facing south PV characteristics curves for a single-crystalline silicon photovoltaic (100W) module

Figures 18, 20, 22 and 24 illustrate current-voltage characteristic curves, while figures 19, 21, 23 and 25 illustrate power-voltage characteristic curves in Winter, Spring, Summer and Autumn for both positions of sun tracking and of facing south have been done for the (100W) module.

It is clear that in winter, at the first period and the second period for the position of sun tracking have better values than facing south position. The maximum power values for them are 31.87and 33.8752W for sun tracking position and 18.58 and 28.6W for the position of facing south, respectively. At the third period, the position of facing south has a better value than for sun tracking; the maximum power values for them are 12.75 and 10.46 W, respectively.

In spring, for the three periods on the day, the position of sun tracking has better values than facing south. The maximum power values for the position of sun tracking and facing south are 39.76W and 38.15W for the first period and for the second period are 40.4736 W and 38.9045W and for the third period are 36.927W and 27.0621W, respectively.

In summer, for the first and third periods on the day the position of sun tracking has better values than of facing south, the maximum power values for the position of sun tracking and facing south in the first period have been obtained as 29.56 W and 28.71W and for the third period are 29.57 W and 27.09 W, but for the second period; it has been found that the position of facing south has better value than sun tracking. The maximum power values for the position of sun tracking and facing south are 27.85 W and 28.37 W, respectively.

In autumn, for the first and third periods on the day the position of sun tracking has better value than facing south, for the first period; the maximum power values for the position of sun tracking and facing south are 32.43 Wand 16.28W and for the third period are 19.4025W and 2.2268W, respectively. But for the second period; it has been found that the position of facing south has better value than of sun tracking the maximum power values for the position of sun tracking and facing south are 23.188 W and 33.348W, respectively.

Table 6 shows the calculated results for single crystalline PV module 100 W at solar noon for summer (July), autumn (October), winter (January) and Spring (April) which have solar radiation on tilted surface by angle 30^o as follows 948, 356.12, 630 and 843 Wm^{-2}, respectively. Also, the maximum power values have been found to be 28.8, 13.2, 21.58 and 40W, respectively. It has been found that better efficiencies are in autumn and spring while small efficiencies are in summer and winter. The input power values have been obtained as follows: 621.98, 233.65, 413.34and 553.09W, respectively. For this module, it has been found that the temperature and incident radiation are very important parameters. In summer high temperature at solar noon decreases the module efficiency while in winter the lower incident radiation decreases the module efficiency. The maximum power values have been achieved in summer and spring while the minimum power values have been achieved in winter and autumn. From the results of Table 6, it is evident that as R_S increased Isc decreased.

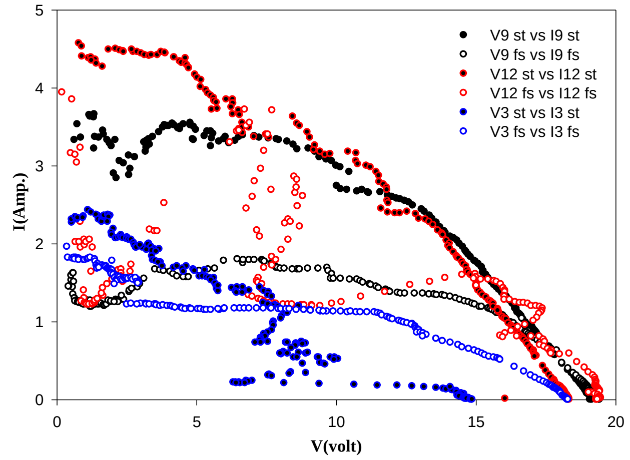

Fig. 18. I-V characteristic curves for the (100W) module in Winter for the positions of sun tracking 15 /1/ 2009 and of facing south 16/ 1/ 2009.

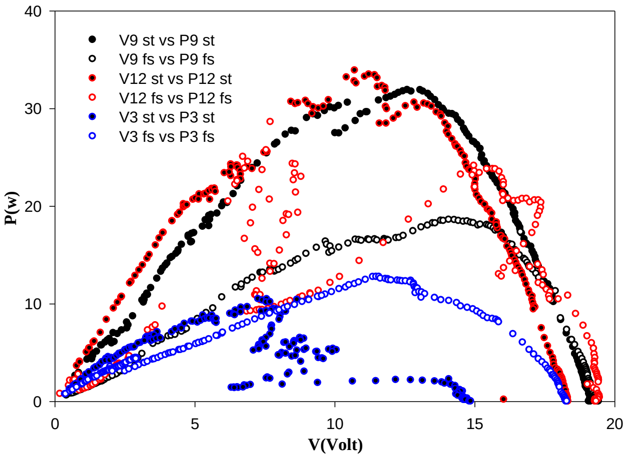

Fig. 19. P-V characteristic curves for the (100W) module in Winter for the positions of sun tracking 15 /1/ 2009 and of facing south 16/ 1/ 2009.

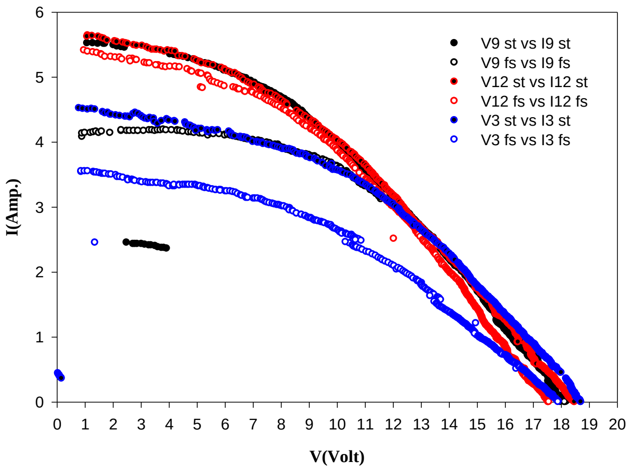

Fig. 20. I-V characteristic curves for the (100W) module in Spring for the positions of sun tracking 13 /4/ 2008 and of facing south 14/ 4/ 2008.

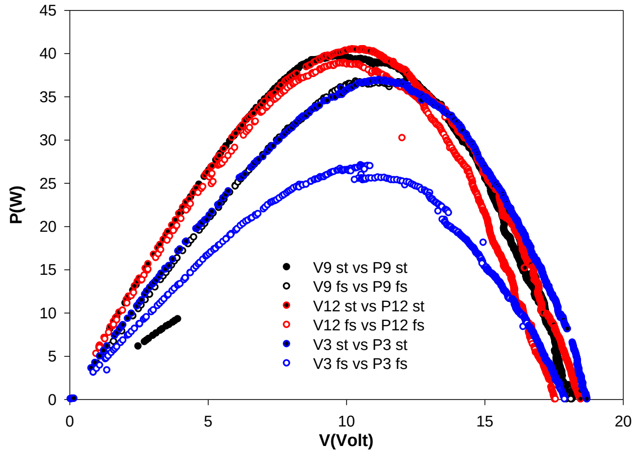

Fig. 21. P-V characteristic curves for the (100W) module in Spring for sun tracking 13 /4/ 2008 and facing south 14/ 4/ 2008.

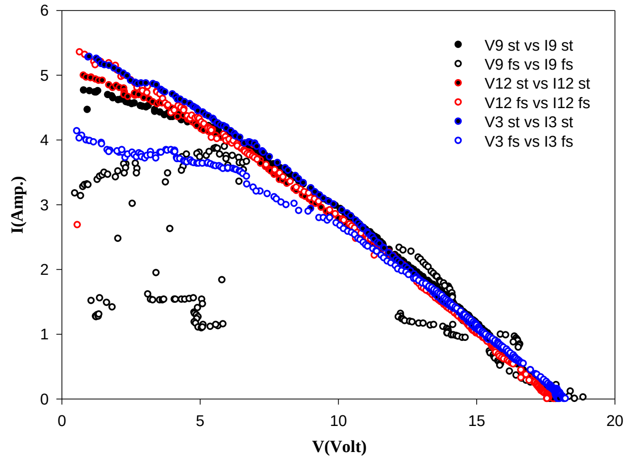

Fig. 22. I-V characteristic curves (100W) module in Summer for sun tracking 17 /7/ 2008 and facing south 18/ 7/ 2008.

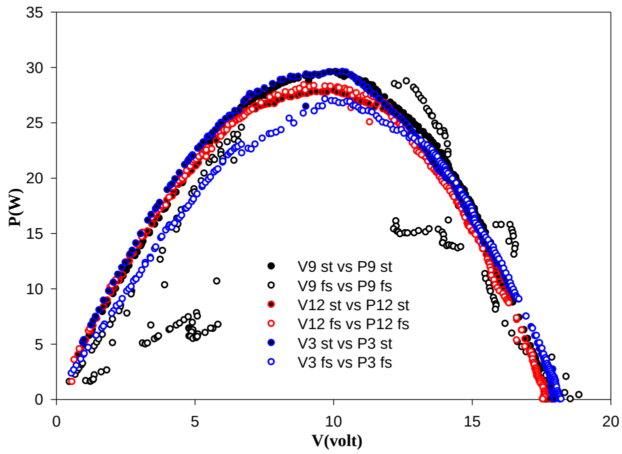

Fig. 23. P-V characteristic curves for the (100W) module in Summer for the positions of sun tracking 17 /7/ 2008 and facing south 18/ 7/ 2008.

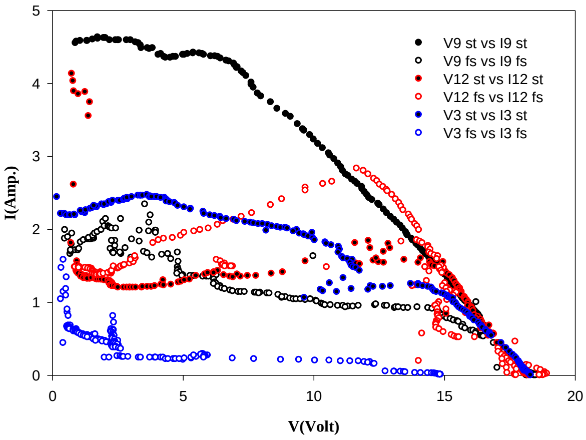

Fig. 24. I-V characteristic curves (100W) module in Autumn for the positions of sun tracking 13 /10/ 2008 and facing south 14/ 10/ 2008.

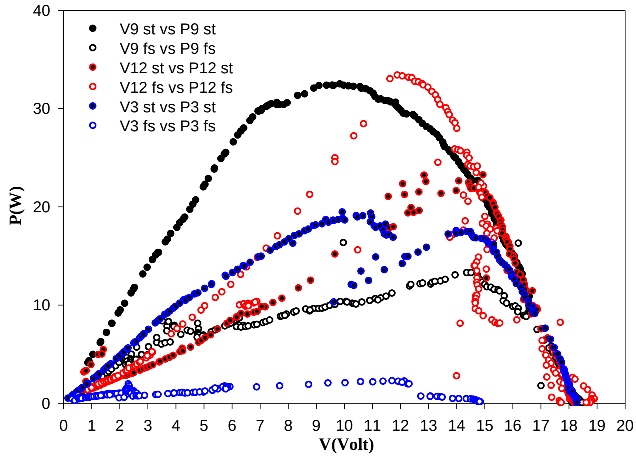

Fig. 25. P-V characteristic curves for the (100W) module in Autumn for the positions of sun tracking 13 /10/ 2008 and facing south 14/ 10/ 2008.

Table 6. Computing values of the electrical parameters of PV solar module (100W) at solar noon:

PVM-100W	Tm_{av}	I_{sc}	V_{oc}	I_R	V_R	F.F	R_s	R_p	η_m(%)
Winter	339	3.75	19.47	1.9	11.5	0.3	6.03	40.51	5.29
Spring	340	5.41	17.57	4	10	0.42	2.47	59.28	7.23
Summer	348	5.5	17.63	3	9.6	0.3	3.18	47.18	4.63
Autumn	334	1.5	19	1.1	12	0.46	10.81	144.85	5.65

4.4 Short circuit current and open circuit voltage for the (100W), (50W) and (17W) modules for the two positions sun tracking and facing south.

It is important to clarify the effects of seasonal temperature variations and spectral irradiance on the performances of photovoltaic solar modules. Two parameters of the modules output, i.e. the short circuit current I_{sc} and open circuit voltage V_{oc} have been used to analyze the above effects for one year.

From figures 26, 27 and 28, it has been found that I_{sc} values increase in summer and spring while decrease in winter and autumn. It is seen that I_{sc} values increase slightly with increasing temperature and decrease with decreasing temperature which is season-dependent. From figures 29, 30 and 31 it is clear that V_{oc} values decrease in summer and spring while increase in winter and autumn, it is evident that V_{oc} values decrease with increasing temperature and increase with decreasing temperature.

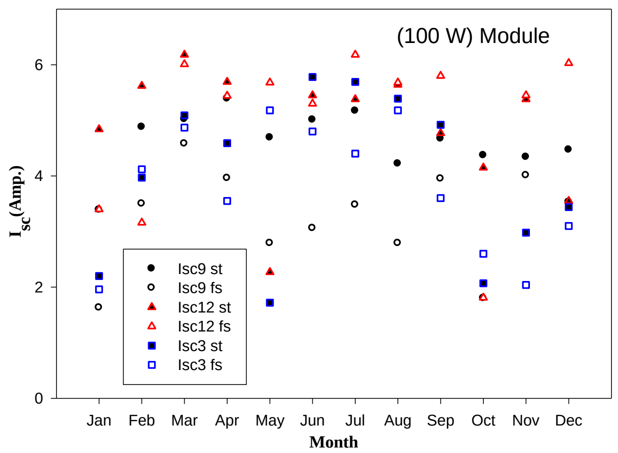

Fig. 26. Short circuit current Isc curves for the PV solar module (100 W) for a completely one year.

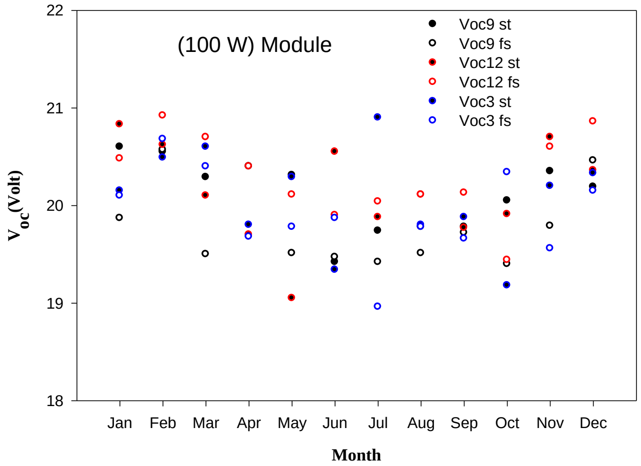

Fig. 27. Open circuit voltage Voc curves for the PV solar module (100W) for a completely one year.

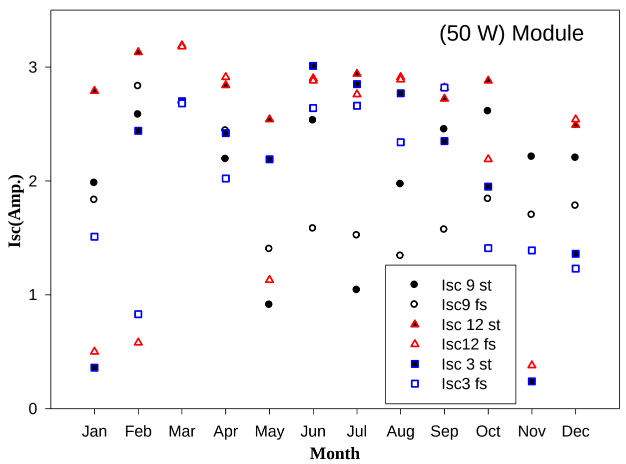

Fig. 28. Short circuit current Isc curves for the PV solar module (50 W) for a completely one year.

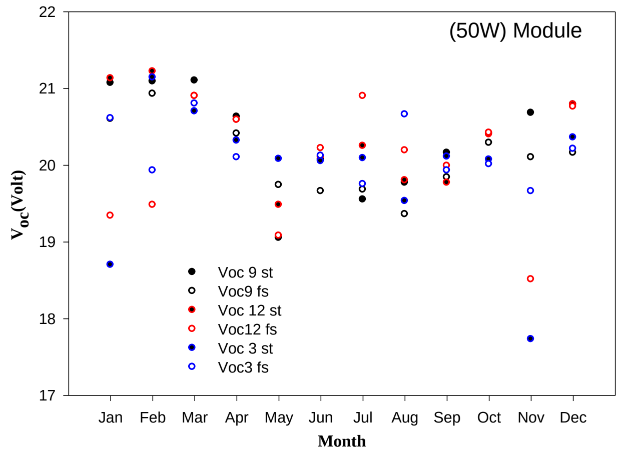

Fig. 29. Open circuit voltage Voc curves for the PV solar module (50W) for a completely one year.

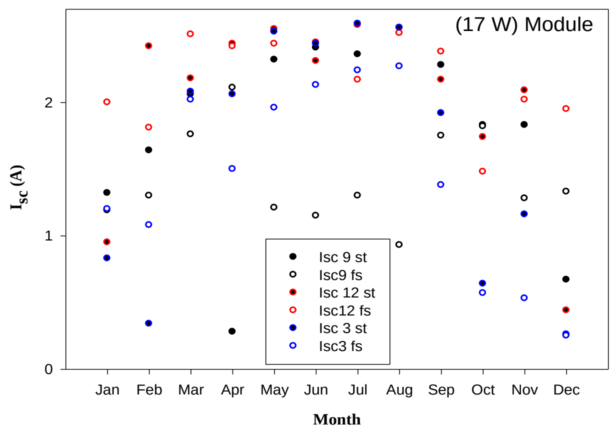

Fig. 30. Short circuit current Isc curves of the (17 W) PV solar module for a completely one year.

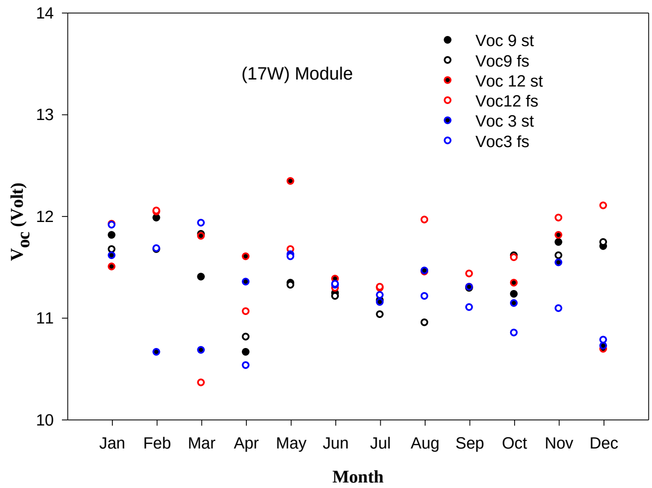

Fig. 31: Open circuit voltage Voc curves of the PV (17 W) solar module for a completely one year.

5. Conclusions

In the present article the electrical performance for 100 W and 50 W monocrystalline silicon and 17 W Triple junction (amorphous silicon) photovoltaic solar modules, with the measurements carried out under real working conditions in Tanta, Egypt. The measurements of the electrical performance of the photovoltaic solar modules were done for two cases: I) sun tracking and II) facing south conditions. The current–voltage and power–voltage characteristics under outdoor conditions were measured, the three modules was situated on the top of Faculty of Science , Tanta University, Tanta ($30^o 41'$). η_m, FF, R_s and R_p for the modules have been calculated for the position facing south by using a computer program. The most important conclusions drawn from the analysis presented above are: Comparisons between the positions facing south and sun tracking of the (50W) module, (100W) module and (17W) module indicated that good results have been noticed for the position sun tracking in the most cases. The efficiency of the (100W) module in winter, spring, summer and autumn are found to be 5.29, 7.23, 4.63 and 5.65%, respectively. The efficiency of the (50W) module in winter, spring, summer and autumn are found to be 9.02, 6.94, 7.28 and 10.55%, respectively. The efficiency of the (17W) module in winter, spring, summer and autumn are found to be 4.1, 3.49, 4.13 and 4.82%, respectively. I_{sc} values for the (50W) module, the (100W) module and the (17W) module increase in summer and spring and decrease in winter and autumn, V_{oc} values decrease in summer and spring and increase in winter and autumn.

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