Investigation of Practical Integral Solar System Performance

Hend Abd El-monem Salama

Electric Power Engineering Department, Higher Institue of Engineering and Technology, New Cairo, Egypt
Email: h.d.61@hotmail.com

ABSTRACT

Today, the world has more interest to expand the renewable energy resources because of shortage of permanent resources. Solar energy is the essential topology resource that has thousands of applications especially in sunshine countries. Several researches have been established and examined in lab to modify and maximize the outputs from solar systems. This paper provides a distinct solar system composed of two panels, fixed and tracking, connected in parallel and a controller Arduino program is used in design of the control unit to study the outputs whether from individual panels or from the integrated panels. Finally, analysis of solar panels' performance is evaluated and discussed.

Keywords : Maximum power point (MPP); maximum power point of tracking panel (MPPT); fixed solar panel; tracking solar panel.

1 INTRODUCTION

GENERATION of electric energy from solar energy has been expanded all over the world countries where it has huge benefits coverage in low power application's sectors such that social, industrial, economics and even healthy life for human. In literature, an extensive researches have been under way to specify and control the effective parameters of the solar system performance affecting on its outputs. A survey of huge number researches of solar system designs is commonly implemented algorithms to achieve the maximum power point (MPP) of standalone systems. The significant target of all researches is advancing and maximizing MPP. Output of solar energy system depends mainly on significant load line under specific atmospheric conditions. Since the solar energy system is nonlinear system, it may deliver MPP at different operating points to the load [1]. Large number of parameters which have the major effects on the MMP are variable according to the nature of the designed solar system. The first factor is the solar panel itself where connection between its cells, the voltage and the current gained from the panel beside the panel material and its size. Irradiance, atmospheric conditions, the components of the systems especially; converter, sensors, and controllers are also impact factors on MPP. The most efficient factor is the inclined angle of solar panel which control on MPP of fixed solar system. Highlight Programmable algorithm techniques of solar tracking system have been extended to examine maximum power point of tracking panels (MPPT). So, several researches present survey to investigate and evaluate their topologies where some of them are ranking techniques such that Perturb and Observation, Incremental Conductance, Constant Voltage, Hill Climbing, Open Circuit Voltage, Short Circuit Current, Fuzzy logic and Neural Network techniques [2], [3], [4], [5]. Most manuscripts inveatigate techniqu's designs to specify their pros and cons. Perturb and Incremental are superior to all other algorithms where they fulfill an efficiency if compared with some other techniques while other researchers prefer Fuzzy and Neural Network techniques science they have higher efficiency [6] [7]. The first technique has many outputs based on develping its versions [8]. Actual experiments deliver the performance of theses techniques based on certain constrains . For example constant voltage technique, Open circuit technique and short circuit technique deliver unaccurate MMP especially for high irridiance with losses while Hill Climbing technique has waste time [5] [7]. Some of them achieves outstanding success when executed in the essential applications used varient sectors around the world countries [9]. Some algorithmic techniques is defined by implemented complexity technique like Current sweep technique, Fuzzy logic and Neural Network techniques [5] [10]. One of converters; Buck, boost and cock can be connected to the controller of solar tracking system to make the controller deliver better outputs [11].

With a lot of executed solar system researches of MPPT, few of them provides practical study about the solar panel performance whether fixed or converted from fixed to movable solar panel [12] [13]. So, this paper presents a practical solar system which is composed of two panels connected in parallel; fixed panel and movable tracking panel. The system is designed and established in the lab with a control unit which has a program designed on Arduino programmable to operate each panel individually or operate the panels together. A designed program which operates the solar tracking panel is depended on the voltage paremeter with optimum contol of seasonal day time. .Control unit has the significant role on operating the tracking panel through electric and mechanical circuits beside controlling the operation of the

IEEE-SEM, Volume 10, Issue 4, April-2019
ISSN 2320-9151

system in three seprate techniques which are called fixed, tracking and integrating techniques. Expremental study is implemented along four seasons of a year and the outputs measurements are analysed and contributed in the paper.

2 PEPERIMENTES AND MESUREMENTS

2.1 Precedure Set-up

Solar system circuit is composed of two solar panels, the first panel is Power Star Polycrystalline 1950 × 990 mm^2, (PSP 300) and the second panel is Power Star Polycrystalline 1640 ×990 mm^2, (PSP 220) as indicated in Fig. 1. Ratings of two panels; maximum voltages, maximum currents, open circuit voltages and short circuit currents are 36 V - 30 V, 8.33 A – 7.33 A, 44 V – 35 V, and 9.16 A – 8.06 A respectively. Control unit of the system contains power supplies [36V-12V-6V], LDR sensors circuit, (Rev 3) Uno Arduino board, relay module, four sensors, selector switches, push buttons and protective elements. Fig. 2 indicates the control unit with configuration of panel components mounted in the lab and charger controller (WELLSEE controller WS-MPPT30 20A 12V/24V). DC loads composed of dc motors and LED units are prepared in schedule to be used for eleven measurements where the maximum load equals to 175 W. The loads schedule is recorded in TABLE 1 used in the three techniques established in the solar system.

Fig. 1. Tracking solar panel and fixed solar panel mounted in the lab roof.

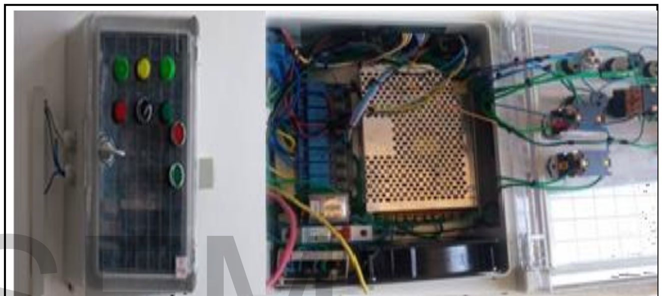


Fig. 2. Control unit with its components.

TABLE 1
SCHEDULE SHEET OF DC LOADS CONNECTED SOLAR PANELS

DC loads	Motor 1 15 W	Motor 2 15 W	Lamp 1 45 W	Lamp 2 45 W	Lamp 3 45 W
Test 1	√				
Test 2	√	√			
Test 3				√	
Test 4	√			√	
Test 5	√	√		√	
Test 6			√	√	
Test 7	√		√	√	
Test 8	√	√	√	√	
Test 9			√	√	√
Test 10	√		√	√	√
Test 11	√	√	√	√	√

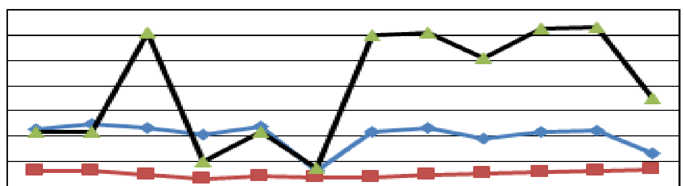
TABLE 2
MAXIMUM OUTPUTS OF THREE TECHNIQUES WITH MEASURED IRRADIATION AND TEMPERATURE

Lux/1000	Temp ^{0}C	Fixed panel	Tracking panel	Integrated panels	Season of year
115	31	102	107.6	45.1	Summer
125.7	31.4	93	108.2	50.1	Summer
115.5	22	95.7	305.7	37.1	Summer
104	16	317.4	49.2	139	Autumn
118	21	331.1	108.5	184.2	Autumn
31	18	79.8	36.3	79.8	Autumn
108	18	453.6	300.9	177.7	Winter
115.5	22	557.2	305.7	251.8	Winter
95	25	400.6	256	153.1	Winter
108.1	28	504.1	313.6	183.7	Spring
112.2	30	572	315.4	254.6	Spring
66.2	34	307	174.7	139.7	Spring

IEEE-SEM, Volume 10, Issue 4, April-2019
ISSN 2320-9151

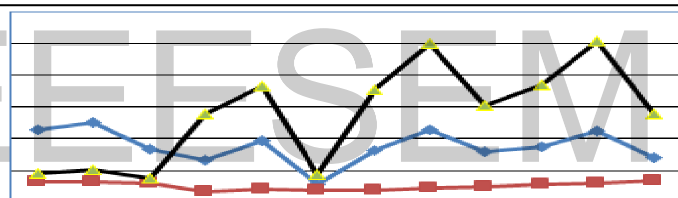
2.2 Experiment Measurements

Along day hours, output measurements are recorded in three times; at the morning, at mid-day time and at the end day time. Then, three measurements for one day over four seasons and twelve outputs for each technique are tabulated in TABLE 2. The outputs of first technique that has tracking panel technique is represented in Fig. 3 while Fig. 4 indicates the output of fixed panel technique. Output of the third technique and the individual outputs of the two panels along one year are recorded in Fig 5 to be studied. Also, analysis of I-V characteristics of two panels used in this system has been activated to be compared per unit area where their material, construction of panel cells and the incident irradiation are the same. So, the two panels are examined under the same conditions, chart of current and voltage of tracking and fixed panels are measured and plotted through selected day time in summer season of the tested year as shown in figures 6 and 7.



	1	2	3	4	5	6	7	8	9	10	11	12
Lux/1000	115	126	116	104	118	31	108	116	95	108	112	66.2
Temp. °C	31	31.4	22	16	21	18	18	22	25	28	30	34
Max. powerW	108	108	306	49.2	109	36.3	301	306	256	314	315	175

Fig. 3. Maximum power output, temperature and irradiation of tracking panel technique.



	1	2	3	4	5	6	7	8	9	10	11	12
Lux/1000	115	126	84.2	66.5	97	27	82	114	79	88.4	112	70.4
Temp. °C	31	31.4	29.5	16	21	18	18	22	25	28	30	34
Max. powerW	45.1	50.1	37.1	139	184	43.3	178	251	153	185	255	139

Fig. 4. Maximum power output, temperature and irradiation of fixed panel technique.

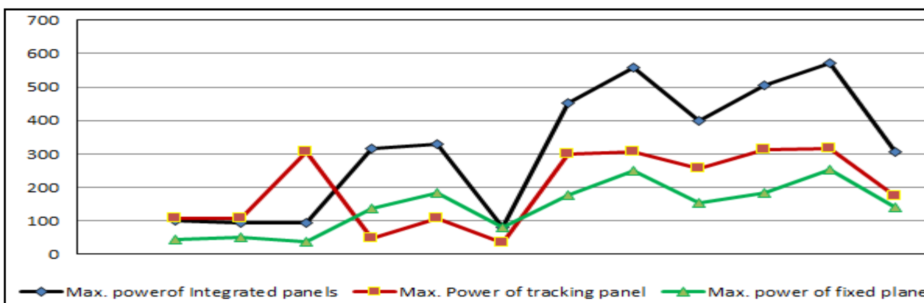


Fig. 5. Maximum power output of the three techniques.

IEEE-SEM, Volume 10, Issue 4, April-2019
ISSN 2320-9151

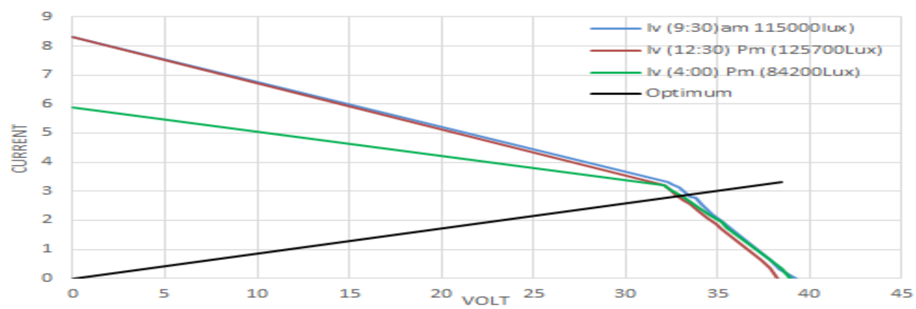


Fig. 6. Current - voltage curve of tracking panel measured in summer season.

Fig. 7. Current - voltage curve of fixed panel measured in summer season.

3 COMPREHENSIVE ANALYSIS OF MEASUREMETS

- The outputs of the three techniques are different while at the end day time of autumn season, solar system for the three techniques generates the least output because of sky clouding and so, this output must be maximized through advancing the system by using capacitors or storage battery to compensate this shortage. Maximum power of tracking panel is larger than the fixed plane output in seasons; summer, winter and spring when sun rays intensity and temperature centigrade are increased. At lower atmospheric temperature, like in autumn season with sky cloudy, fixed panel has the maximum power than the tracking panel. Also, the change of irradiation along the year is more compatible with the outputs of fixed panel than the tracking panel.
- Third technique is the most efficient technique where its output are the largest along the year. So, integrating two or more panels whether identical in type or different types like the case study can maximize the total outputs.
- I-V characteristic curves of two panel reflect the performance of them along the day time. They have not like ideal I-V curves of solar panels because of connected loads. Also, Optimum curve of the tracking panel is more efficient than that owned by fixed panel for the same loads schedule. At the end of day time, the least output is provided from the fixed panel according its characteristic curve. It is clear that short circuit current and open circuit voltage of tracking panel are larger if compared with the fixed panel along the day time measurements where short circuit current records 8.3 Ampere exceeding by 20 percent than the fixed panel while open circuit voltage of tracking panel is 39.27 volt increasing 18 percent than the open circuit voltage of the fixed panel. Performance of each panel is bounded by incident sun rays on the panel and the connected loads in the tested solar circuits. At day time, the irradiation intensity are measured in the morning, mid-time of day and the end time of day that equals 115000 Lux, 125700 Lux and 84200 Lux respectively. The performance of the panel is assessed by adapting its ability for absorbing the sun rays. Let the incident sun rays is constant on the panels' area and so, sun rays intensity unit area for each panel is estimated as following:

$$\text{Irradiation/ unit area } (m^2) = \frac{Lux}{Plane\ area} \tag{1}$$

Then, for tracking panel, incident sun rays are 59570 lux/m^2, 65112.67 lux/m^2 and 43615 lux/m^2 respectively while fixed panel has been received 70830.25 lux/m^2, 77420lux/m^2 and 51860.1 lux/m^2 during the three times. Obviously without a doubt, tracking panel is more efficient than fixed panel since it has the large area.

IEEE-SEM, Volume 10, Issue 4, April-2019
ISSN 2320-9151

- Efficiency of the solar panel is estimated according to the equation [14]:

$$\eta \equiv \frac{P_{out}}{P_{in}} \equiv \frac{V_{oc} \times I_{sc} \times FF}{P_{in}} \quad (2)$$

Where,

P_{out} is the output power from the panel.
P_{in} is the input power of panel.
V_{oc} is the open circuit voltage.
I_{sc} is the short circuit current.
FF is the Fill Factor

$$FF \equiv \frac{V_m \times I_m}{V_{oc} \times I_{sc}} \quad (3)$$

Or

$$\eta \equiv \frac{P_{out}}{A_{panel} \times G} \quad (4)$$

where,

P_{out} is the output power from the panel.
A is the panel area.
G is horizontal global solar radiation, - assume 1000 W/ m^2 under several certain conditions.

- Equation 2 estimates the panel efficiency which depends mainly on several conditions like panel area and atmospheric conditions. If equation 2 is applied on case study, the solar tracking panel has efficiency percent exceeds than fixed panel because of own area. Performance quality of case study can be examined by estimating FF of solar panels to be compared. According to equation 3, Fig. 7 and Fig. 8, FF equals to 0.4063 and 0.2629 for tracking and fixed panels respectively. Fill factor depends mainly on the connected load value that not exceed than 175W. This analysis proves in general the tracking panel has the best quality.

4 CONCLUSIONS

According to the experimented solar system and measurements analysis, significant facts are concluded:

- The tracking panel provides the maximum power utilizing most of incident sun rays along the day time and also, it has higher performance quality than the fixed panel performance.
- The outputs of solar fixed panel is the maximum when weather condition has lower temperature or cloudy weather.
- Solar tracking panels can operate standalone or merge with solar fixed panels to maximize the outputs and compensate the shortage of them.
- I-V characteristics curves of solar panels must be checked and recorded in technical datasheets. Since the operating solar panels degrade, periodically check must be attended to evaluate panel quality performance.
- Solar system composed of identical panels or merge tacking panel and fixed panel can be established with control unit to maximize the outputs to be used in commercial, residential and even industrial sectors.
- Clouds or shadows causes outputs shortage that must be compensated by adding capacitors or storage batteries to develop the system output.

5. References

[1] A. Rai, B. Awasthi, S. Singh, C. K. Dwivedi, "A Review of Maximum Power Point Tracking Techniques for Photovoltaic System", International Journal of Engineering Research, June, 2016.
[2] S. E. Babaa, M. Armstrong, V. Pickert, "Overview of Maximum Power Point Tracking Control Methods for PV Systems, Journal of Power and Energy Engineering, 2014.
[3] S. Gupta, N. Sharma, "A Literature Review of Maximum Power Point tracking from a PV array with high Efficiency, IJEDR, Volume 4, Issue 1, 2016.
[4] N. Onat, "Review Article, Recent Developments in Maximum Power Point Tracking Technologies for Photovoltaic Systems", Hindawi Publishing Corporation International Journal of Photoenergy, Article ID 245316, 2010.
[5] A. Rai, B.Awasthi, S. Singh, C. K. Dwived, "A Review of Maximum Power Point Tracking Techniques for Photovoltaic System", International Journal of Engineering Research, Volume No.5, Issue No.6, pp : 539-545, June 2016
[6] K.V, M. Malhotra, Ramakrishna N, S. Prabu.R, "Literature Review on Solar MPPT Systems, Advance in Electronic and Electric Engineering, Volume 4, Number 3, pp. 285-296, 2014.
[7] B. P. Pakkiraiah, D. Sukumar, "Review Article, Research Survey on Various MPPT Performance Issues to Improve the Solar PV System Efficiency", Hindawi Publishing Corporation Journal of Solar Energy, Article ID 8012432, 2016.

IEEE-SEM, Volume 10, Issue 4, April-2019
ISSN 2320-9151

[8] G. Remy, O. Bethoux, C. Marchand, H. Dogan, "Review of MPPT Techniques for Photovoltaic Systems", Laboratoire de Génie Electrique de Paris (LGEP) / SPEE-Labs, 2009.
[9] A. Soualmia, R. Chenni, "A Survey of Maximum Peak Power Tracking Techniques used in Photovoltaic Power Systems", Future Technologies Conference, San Francisco, United States, 2016.
[10] S. Kumar, M. K. Mishra, A.Yadav, V. K. Pal, "Power comparison of MPPT techniques for solar system", International Journal of Computer Applications, The National Conference on Role of Engineers in National Building, 2016.
[11] U. T. Kut, P.S. Ratnaparkhi, " Literature Survey on Maximum Power Point Tracking (MPPT) Technique for Photovoltaic (PV) System", International Journal of Advanced Research in Engineering and Applied Sciences, Vol. 2, No. 12, December , 2013.
[12] M. Mahendran, G.C. Lee, Thanikaikumaran, "An Experimental comparison study between Single-Axis Tracking and Fixed Photovoltaic Solar Panel Efficiency and Power Output", Case Study in East Coast Malaysia, 2017.
[13] H. A. E. M. Salama, A. T. M. Taha, "Practical Implementation of Dual Axis Solar Power Tracking System", MEPCON, Twentieth International Middle East Power Systems Conference, Cairo University, Egypt, 2018.
[14] B. V. Chikate, Y.A. Sadawarte, "The Factors Affecting the Performance of Solar Cell", International Conference on Quality Up-gradation in Engineering, Science and Technology, published in International Journal of Computer Applications, 2015.