Asian Journal of Research and Reviews in Physics

6(1): 1-13, 2022; Article no.AJR2P.71993
ISSN: 2582-5992

Angle Dependence of Solar Power Capacity: The Case of Setit Humera

Simenew Assefa Mulat [a*] and Merhawi Abreha [b]

[a] *Department of Physics with Condensed Matter Physics Specialization, Hawassa University, Daye Campus, Ethiopia.*
[b] *Department of Physics with Material Science Specialization, Aksum University, Ethiopia.*

Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJR2P/2022/v6i130173

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/71993

Original Research Article

Received 10 July 2021
Accepted 15 September 2021
Published 20 January 2022

ABSTRACT

The solar power capacity depends on orientation angle of the solar panel. This study evaluates the angle dependence of solar power capacity for a summer season in 2017. Using three solar panels, with 10 Watt capacity each placed on a metallic frame to facilitate changing tilt and azimuth angles independently. Experiments were done for the first six days of three months, and the first three days of each month were used to measure voltages for different tilt angles by changing from 0° to 26° in steps of 2^o. The remaining three days of a week of every month, the middle solar panel was fixed at a tilt angle that yielded maximum power while the two panels were moved with azimuth angles from 0^o to 27^o in steps of 3^o to clockwise and counterclockwise with respect to the middle solar panel. A digital multimeter was used to record the circuit voltage of the solar panels with 10 ohms resistor serving as a load. Data gathering was done every ten minutes, during the daytime from 9:30 am to 16:30 pm. The study has shown that the maximum power output was obtained at the tilt angle of 4^o in June and July, 2^o in August and a season tilt was found at 4^o. Maximum solar power outputs were obtained when solar panels facing east and west were oriented between 0^o and 3^o. This recommends that the maximum solar power production depends on the tilt angle of 4^o and clockwise and counterclockwise of 3^o orientation for this geographical location.

Keywords: Solar power capacity; tilt and azimuth angle; photovoltaic effect; load resistor.

**Corresponding author: E-mail: simenew@gmail.com, simenehassefa@gmail.com;*

1. INTRODUCTION

Energy is the primary and the universal measure of all kind of work by human beings. With day to day technological improvement, energy generated from fossil fuels can never fulfill the increasing requirement and consumption of energy. In recent times, environmental polluting was increasing all over the world, since the extensive use of none renewable energy for the fabrication of electricity and engine combustion. Thus, due to the recent shortage of fossil fuels and to prevent air pollution, power generation from renewable energy should be considered as a new alternative. Solar energy is one of the renewable sources of energy. It attracts large interest out of the other renewable energy, because of its great futures like it's easy to install, and requires minimum maintenance, and more. Solar energy can be converted into electricity directly using a solar panel which converts sunlight in to electricity using photovoltaic effect [1]. The output solar power from the solar panel can be computed,

$$P = \frac{V^2}{R} \qquad (1)$$

Where: $P =$ output power in Watts, $V =$ Voltage in Volts $\mathrm{R} =$ the resistance of the load in ohms. However, the performance of the photovoltaic module depends on the light intensity of the sun which turns depends on weather conditions and the orientation of the solar panel [2]. Hence, the tilt and azimuth angle plays an important role in the efficiency of the solar panel. Therefore, the effective operation of solar panel installation to generate solar power from the solar depends on the tilt and azimuth angle of the solar panel. The aim of this study is to determine the angle dependence of solar power capacity at Setit Humera during the summer season. More specifically,

- ✓ To estimate the solar power capacity at different tilt and azimuth angles.
- ✓ To find out at which tilt and azimuth angle, the solar panel is achieving maximum power output.

1.1 Orientation of Earth with Respect to the Sun

The earth by itself swaps around its polar axis over a period of 24hours. The distance between the sun and earth varies by $\pm$1.7 % due to the earth revolves around the sun in an elliptic orbit once per year [3]. The mean earth distance is 1.459×10^{11} m. The diameter of the sun is 1.39×10^{9}m and that of the earth $1.27 \times 10^{7}\ m$ [4]. The variation in distance between the sun and the earth is given by:

$$D = 150\{1 + 0.017 sin\ [\frac{360(n-93)}{365}]\}\ x10^{7} km \qquad (2)$$

Where: n is the number of the day in the day of years.

Using Fig. 1, the shortest distance between them is approximately $1.47 \times 10^{8}\ km$ and known as perihelion, occurred on January 2 The longest distance is around 1.52×10^{8} km, is called the aphelion, it reached on July 2. The difference in the earth-sun distance between the aphelion and perihelion does not have a significant effect on climate [5]. If effects of the atmosphere are snubbed, a position in the northern hemisphere will collect its maximum solar energy on the longest day when the earth's axis is tilted towards the sun [4]. This is the day of the summer solstice.

1.2 Basic Solar Geometry Angles

The position of the sun in the sky as per any location could be located by the solar angles. The rotation of the sun varies depending on the latitude and longitude of the location [4]. Therefore, the solar angles will be different for the locations at different latitudes and longitude during the same period. Thus, solar angles are commonly used to specify the apparent position of the sun in the sky.

1.2.1 Equation of solar angle

The declination angle (δ) is defined as the angle between the sun lights and the equator plane [6].

$$\delta = 23.45°[\frac{sin[360°(284+n)}{365.25}] \qquad (3)$$

Where n is the day of the year (1st January) to 365, or 366 [7].

Hour angle (**ω**) the angle between the longitude of sunlight and the longitude of the location [8].

$$\boldsymbol{\omega} = {}^{360^0\ (ST - 12hr)}/_{d} \qquad (4)$$

Where d = 24 hr. and ST is the solar time (in hours).

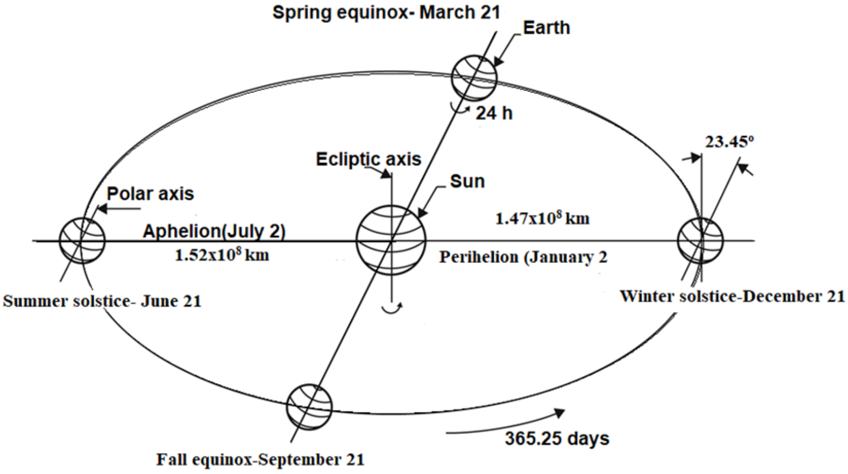

Fig. 1. The geometry of the sun-earth relationships

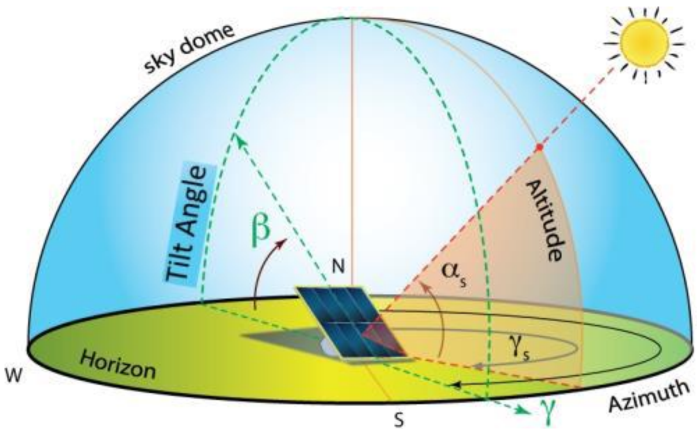

Fig. 2. Solar orientation angles

Solar altitude angle (α) the solar altitude angle is the angle between the sun's rays and a horizontal plane [9].

$$\alpha = sin^{-1}[sin\,(L)\,sin(\delta) + cos\,(L)\,cos(\delta)\,cos(\omega)] \quad (5)$$

The change between true solar time and mean solar time is known as the equation of time (ET).

$$\text{ET (in minute)} = 9.87\,\sin(2B) - 7.53\cos(B) - 1.5\sin(B) \quad (6)$$

Where:

$$B = \frac{360(n-81)}{365.25} \cong \frac{369(284+n)}{365.25} \quad (7)$$

And local solar noon,

$$12 - \text{equation of time in hours on that day} \pm \frac{-(\varphi.r-\varphi.o)}{15} \quad (8)$$

Where: φ_r = Longitude of reference meridian and φ_o = Longitude of the location meridian. The equation of time is a correction factor that depends on the time of the year, ranging from +16.3 min in November to -14.4 min in February [10]. Solar time and local standard time is different from each other. Local solar time is derived by the actual sun position on the sun path of each particular day, whereas the solar time is derived based on reference meridians [11]. Again the mean solar time can be obtained by the equation:

$$Solar\ time - standard\ time = 4(L_{st} - L_{loc}) + equation\ of\ time \quad (9)$$

Where: L_{st} is the standard meridian for the local time zone, L_{loc} is the longitude of the location in degree, that is,

$$0^o < L < 360^O \quad (10)$$

1.3 Solar Panel Orientation

The orientation of the solar panel is described by its azimuth and tilt angles [12]. Tilt angle defined that the angle between the solar panels' surface and the horizontal plane in the North-South direction [2]. When the solar panels are most efficient, they are perpendicular to the sun's rays. Therefore, this is refers that the tilt angle is optimum and the solar panels generate maximum solar power. Many investigations have been carried out to determine the best tilt angle for such systems. Whereas some researchers suggest two values for the tilt angle, one for summer and the other for winter, such $as\ L \pm 20°$, $L \pm 8°$, $L \pm 5°$, $L \pm 10^o$, where L is the latitude, "+" for winter, and "−" for summer [12]. In other groups, during summer, the incident insolation is maximized for a surface with an inclination $10^O - 15^O$ less than the latitude during winter and $10^O - 15^O$ more than the latitude during summer [9].

2. MATERIALS AND METHODS

2.1 Description of the Study Area

This study was conducted at Setit Humera which is located at 1364km North of Addis Ababa, Ethiopia at the $14^0\ 17'12''$N and $36^0\ 36'\ 13''$. It is situated in the semi-arid tropical belt of North Ethiopia and is characterized by a sub-humid type of climate with an average annual rainfall of about 661 mm. With annual average maximum temperature is 31°C and the minimum temperature 24.2°C.

2.2 Experimental Materials

The materials used in this experiment are the solar panel, Load resistor, Digital multimeter, Switch, Electrical wire, Protractor, Ruler, Scientific calculator, and GPS.

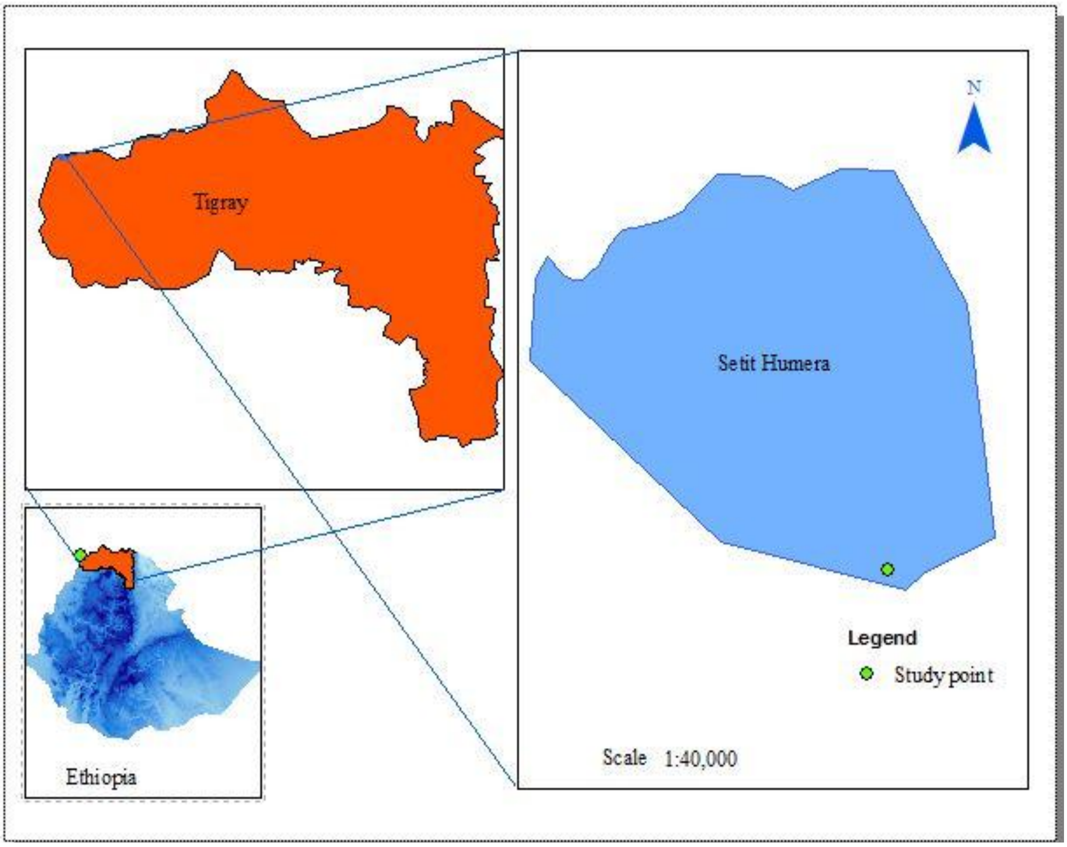

Fig. 3. Map of the study area

2.3 Experimental Procedures

1. During the days, before the data were collecting, the values of the Julian day number, the equation of time, solar time, declination angle, hour angle, and solar altitude angles were calculated.
2. The latitude and longitude of the selected site were measured by GPS 60.
3. True North-South and East-West directions were arranged using GPS 60.
4. Each three solar modules with 10 Watt were placed parallel to North-South direction.
5. All three solar modules were installed on the same altitude and connected to the 10Ω load resistor, three switches, and a digital multimeter as shown in Fig. 3.
6. The tilt and azimuth angle of the panel were measured using ruler and protractor.
7. Tilt angles of all modules were varied at the same time starting from 0^o to 26^o with in steps of 2^o in the first three days of selected a week of a month.
8. Output voltages for the corresponding tilt angles were measured using a digital multimeter.
9. The second three days of a week azimuth angles were varied from 0^o to 27^o insteps of 3^o relative to the fixed middle module.
10. Output voltages for the corresponding azimuth angle were measured using a multimeter.
11. Using equation 1 calculate the output power.
12. The same procedures were repeated for the remaining two months.

The experimental set-up as shown in Fig. 4 is a metal frame with revolving pedestal properly designed. A revolving metal frame can rotate 360^0. It can change the position of all solar panels from east to west or west to east. And can move from the axis in relation to the horizontal plane $0^0\ up\ to\ 90^0$. All three solar panels mounted on a metal frame with revolving pedestal. The tilt angle of all three solar panels can be adjusted from 0^o to 26^o in step of 2^o on a metal frame with the same time. All three solar panels arranged in truth south face because of Ethiopia is located between $33^0\ and\ 48^0$ East longitudes and between $3^0\ and\ 15^0$ North latitude. On the other hand, by fixing the middle solar panel to south face with a tilt angle that has resulted in maximum power output during the measurement. The other two border solar modules were moved with azimuth angle from 0^o to 27^o in a step of 3^o to the direction of east and west with relative to the middle fixed solar panel. However, these two modules could be changed their direction from 0° to 45° towards east and west with respect to the middle panel on a revolving pedestal of metal frame in the axis of rotation. The three switches used to make on/off the circuit when taking the voltage readings by digital multi-meter independently form each solar modules. 10Ω of load resistor used to as closed-circuit.

Fig. 4. Experimental set up

2.4 Method of Data Collection and Analysis

The data collection was done during the summer season from June up to August 2017. During the data collecting, measurements were taken every ten minutes time intervals during the daytime, starting from 9:30 am up to 16:30 pm for seven hours with 22 trials per day. During the first three days of each selected week, the measurement made average output voltage and power for each 22 trials for the corresponding tilt angle. The remaining three days of each selected week, the measurement made average voltage output in 22 trials with their respective times in every ten minutes time intervals and output power for the corresponding azimuth angle. The results of tilt and azimuth angles were analyzed separately based on the generated average output powers of each solar panel.

$$\frac{V_1+V_2+V_3}{3}\ or\ \frac{\left[\frac{V_{w1}+V_{w2}+V_{w3}}{3}\right]+\left[\frac{V_{E1}+V_{E2}+V_{E3}}{3}\right]+\left[\frac{V_{m1}+V_{m2}+V_{m3}}{3}\right]}{3} \quad (11)$$

Therefore, average output voltage from the first three consecutive days (15/06/17, 16/06/17 and 17/06/17), was used to compute the optimum tilt angle. The average output voltage for the remaining three consecutive days (18/06/17, 19/06/17 and 20/06/17) was used to compute the optimum azimuth angle. And also the same procedure was repeated for the remaining two weeks of the months to analyze the data. Where: $\left[\frac{V_{w1}+V_{w2}+V_{w3}}{3}\right]$ = the voltage generated by the west module with relative to the middle for only one trial. $\left[\frac{V_{E1}+V_{E2}+V_{E3}}{3}\right]$ = voltage generated by the east module with relative to the middle for only one trial. $\left[\frac{V_{m1}+V_{m2}+V_{m3}}{3}\right]$ = the voltage by generated by the middle module for only one trial. Output powers from the three solar panels with different tilt angle were computed using equation (1) with the fixed 10 Ω resistor.

$$\sum_{i=1}^{22}\frac{1}{R}\left(\frac{(v_1+v_2+v_3)^2}{3}\right) = total\ \text{average output power}\ (P_i) \qquad (12)$$

Where: v_1 , v_2 & v_3 the average output voltages for the selected three days of each month.

3. RESULTS AND DISCUSSION

3.1 South Facing Solar Panel with Different Tilt Angles

The average output voltages from three solar modules for the first three days of each month was computed using [11]. The total average output powers generated by each solar panel with the corresponding tilt angles had to be computed using equation [12] and then summarized the result value in Table 1 as a sample for june inorder to reducecroding. In order to make it easy and clear objective comparison between the different tilt angle and solar power capacity, all the three months of computed cumulative average output solar powers and the corresponding tilt angles are summarized in Table 2. and plotted on a graph as shown in Fig. 4. Table 1 shows at each tilt angle with 22 trials in the day, the average output powers from each 10-Watt solar module were not increasing uniformly during morning time until noon time and then were not decreasing uniformly during afternoon time. This is due to, the variation of atmospheric condition such as the humidity, temprature and clouds.

The result revealed in Table 2 and Fig. 4 maximum total average power output from solar modules was 16.97W and 16.67W which corresponds to the tilt angle of 4^o in June and July respectively. On the other side, 13.56W for August with the corresponding tilt angle of 2^o. Consequently, the season maximum average power output computed at 4^o. Since 4^o is the mode of the data during a season. At 4^o, average power output increased by 1.56% of for a panel installed horizontally (0^o tilt angle). At 4^o tilt angle for a season is more perpendicular to the sun's light than the other tilt angle. So, it can be decided that 4^o is the optimum tilt angle for the south faced solar panel in Setit Humera as determined by this experiment.

3.2 Azimuth Angle of Solar Panel

One panel moved towards east and the other panel towards the west at different azimuth angle with relative to the middle panel which is fixed at optimum tilt angle. Power also generated.

When determining the best orientation of PV system is showing in Fig. 5 as a sample using the month of June. And randomly, (0^o, 3^o, 12^o, and 27^o) of 10 azimuth angles are showing as a model in order to reduce crowding. However, from the average power versus time graphs indicate that the computed average power increased gradually from early morning until noon. Then, it decreases gradually until late afternoon because of, the sun rays change its position due to the time. Therefore, by changing the direction of panels were obtained extra powers throughout the day.

3.2.1 Solar panel moved towards the west

The result depicted in Table 3 and Fig. 6 shows that the maximum average output powers observed (14.03W, 14. 19W, 13.57W and 13.93W) in June, July, August and season respectively which corresponding to azimuth of 3^o. It can therefore be conclude that 3^o the optimal azimuth angle for the solar panel in this geographical location as determined from this experiment.

Table 1. Calculated average voltages and average powers were for three days with the corresponding tilt angles in June.

T.A	Qua	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T15	T16	T17	T18	T19	T20	T21	T22
0	A.v	1.14	1.38	2.28	2.54	2.75	2.31	2.97	2.99	3.32	3.54	3.14	3.24	3.32	3.19	3.18	3.15	3.14	2.9	2.85	1.59	1.59	0.97
	A.P	0.13	0.19	0.52	0.65	0.76	0.53	0.88	0.9	1.1	1.25	0.99	1.05	1.1	1.02	1.01	0.99	0.98	0.84	0.81	0.25	0.25	0.09
2	A.v	2.09	2.27	2.34	2.49	2.67	2.95	2.9	2.9	3.9	3.92	3.71	3.34	2.88	3.16	2.38	2.17	2.99	2.98	2.9	1.28	1.41	1.2
	A.P	0.44	0.52	0.55	0.62	0.71	0.87	0.84	0.84	1.52	1.53	1.38	1.11	0.83	1	0.57	0.47	0.89	0.89	0.84	0.16	0.2	0.14
4	A.v	2.11	2.25	2.51	2.58	2.72	2.91	2.96	3.18	3.92	3.25	3.18	3.54	3.51	3.16	3.37	3.06	2.26	2.25	1.83	1.75	1.54	1.37
	A.P	0.45	0.51	0.63	0.67	0.74	0.84	0.88	1.01	1.54	1.06	1.01	1.25	1.23	1	1.14	0.94	0.51	0.51	0.34	0.31	0.24	0.19
6	A.v	2.02	2.34	2.39	2.51	2.7	2.74	2.96	2.96	3.9	3.13	3.11	3.03	3.08	3.04	3.21	3.03	2.73	2.71	2.61	2.37	1.29	1.17
	A.P	0.41	0.55	0.57	0.63	0.73	0.75	0.88	0.88	1.52	0.98	0.97	0.92	0.95	0.93	1.03	0.92	0.75	0.74	0.68	0.56	0.17	0.14
8	A.v	1.97	2.09	2.29	2.46	2.62	2.86	2.92	2.93	3.15	3.31	3.01	3.07	3.08	3.06	3.14	2.93	2.9	2.78	2.67	2.56	1.34	1.26
	A.P	0.39	0.44	0.53	0.61	0.69	0.82	0.85	0.86	0.99	1.1	0.91	0.94	0.95	0.93	0.99	0.86	0.84	0.77	0.71	0.65	0.18	0.16
10	A.v	1.89	2.19	2.38	2.31	2.39	2.72	2.53	2.56	3.11	3.24	3.4	3.34	3.23	3.2	2.29	2.05	2.05	2.15	2.14	2.13	2.16	1.06
	A.P	0.36	0.48	0.57	0.53	0.57	0.74	0.64	0.66	0.97	1.05	1.16	1.11	1.05	1.02	0.52	0.42	0.42	0.46	0.46	0.46	0.47	0.11
12	A.v	1.8	2.09	2.34	2.39	2.67	2.84	2.88	2.95	3.07	3.08	2.2	2.24	2.43	2.1	2.26	2.33	2.65	2.8	2.96	2.82	2.55	1.55
	A.P	0.33	0.44	0.55	0.57	0.71	0.81	0.83	0.87	0.94	0.95	0.49	0.5	0.59	0.44	0.51	0.54	0.7	0.79	0.88	0.8	0.65	0.24
14	A.v	1.73	2.07	2.7	2.34	2.62	2.74	3.01	2.08	3	2.59	2.05	3.02	2.27	2.5	2.2	2.71	2.66	2.76	2.7	2.66	2.47	2.21
	A.P	0.3	0.43	0.73	0.55	0.69	0.75	0.91	0.43	0.9	0.67	0.42	0.91	0.51	0.63	0.48	0.73	0.71	0.76	0.73	0.71	0.61	0.49
16	A.v	1.61	2.05	2.07	2.18	2.42	2.58	2.84	2.74	2.94	2.9	2.07	2.13	3.05	2.88	2.19	2.93	2.73	2.55	2.41	2.32	2.3	2.22
	A.P	0.26	0.42	0.43	0.47	0.58	0.67	0.81	0.75	0.87	0.84	0.43	0.45	0.93	0.83	0.48	0.86	0.75	0.65	0.58	0.54	0.53	0.49
18	A.v	1.47	1.98	2.14	2.2	2.53	2.52	2.58	2.52	2.97	2.82	2.76	2.83	2.84	2.3	2.75	2.42	2.33	2.22	2.21	2.25	2.07	2.06
	A.P	0.22	0.39	0.46	0.48	0.64	0.64	0.67	0.64	0.88	0.8	0.76	0.8	0.8	0.53	0.75	0.59	0.54	0.49	0.49	0.51	0.43	0.42
20	A.v	1.33	1.84	2.02	2.09	2.13	2.37	2.54	2.95	2.81	2.83	2.89	2.97	2.82	2.83	2.06	2.75	2.27	2.17	2.1	2.02	2.03	1.44
	A.P	0.18	0.34	0.41	0.44	0.45	0.56	0.64	0.87	0.79	0.8	0.83	0.88	0.8	0.8	0.42	0.75	0.52	0.47	0.44	0.41	0.41	0.21
22	A.v	1.21	1.33	1.57	2.04	2.32	2.38	2.45	2.79	2.96	2.87	2.95	2.96	2.95	2.95	2.96	2.24	2.05	1.94	1.94	1.98	1.94	1.65
	A.P	0.15	0.18	0.25	0.41	0.54	0.57	0.6	0.78	0.88	0.82	0.87	0.87	0.87	0.87	0.87	0.5	0.42	0.38	0.38	0.39	0.38	0.27
24	A.v	1.1	1.7	0.99	1.07	2.51	2.41	2.51	2.83	2.8	2.57	2.56	2.69	2.77	2.45	2.22	2.11	2.24	2.3	2.24	2.21	1.91	1.89
	A.P	0.12	0.29	0.1	0.11	0.63	0.58	0.63	0.8	0.79	0.66	0.65	0.73	0.77	0.6	0.49	0.45	0.5	0.53	0.5	0.49	0.36	0.36
26	A.v	1.12	1.59	1	1.02	1.46	1.95	2.32	2.74	2.87	2.92	2.95	2.63	2.77	2.65	2.53	2.56	2.49	2.21	2.07	2.02	1.88	1.65
	A.P	0.12	0.25	0.1	0.1	0.21	0.38	0.54	0.75	0.82	0.85	0.87	0.69	0.77	0.7	0.64	0.65	0.62	0.49	0.43	0.41	0.35	0.27

Table 2. Computed total average power with the corresponding tilt angles

Tilt angle (Degree)	Computed average generated solar power(W)			
	June	July	August	Season
0	16.72	16.11	13.18	15.34
2	16.31	16.49	13.56	15.45
4	16.97	16.67	13.11	15.58
6	16.62	16.4	11.55	14.86
8	16.15	16.14	11.34	14.54
10	14.21	14.58	11.28	13.36
12	14.11	14.56	11.25	13.31
14	14.04	14.16	11.23	13.14
16	13.62	13.95	9.96	12.51
18	12.92	12.72	9.52	11.72
20	12.43	12.36	8.58	11.12
22	12.24	12.1	8.49	10.94
24	11.13	11.67	8.46	10.42
26	11.03	10.88	7.81	9.91

Table 3. Computed total average output power for east faced in three selected days of each month

Azimuth angle (Degree)	Computed total average generated power(W)			
	June	July	August	Season
0	13.4	14.15	13.46	13.67
3	14.03	14.19	13.57	13.93
6	13.2	13.60	13.32	13.37
9	13.04	13.37	13.15	13.19
12	13.03	13.30	13.02	13.12
15	12.73	13.19	13.01	12.98
18	12.44	12.31	13.01	12.59
21	12.29	12.28	13.01	12.53
23	12.24	12.23	13.01	12.49
27	12.16	9.85	12.75	11.64

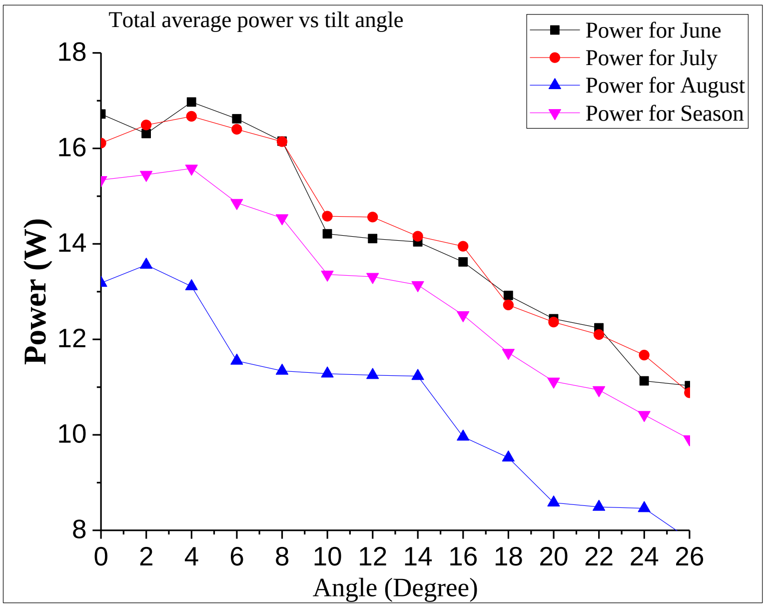

Fig. 5. Graph of average output power versus tilt angles

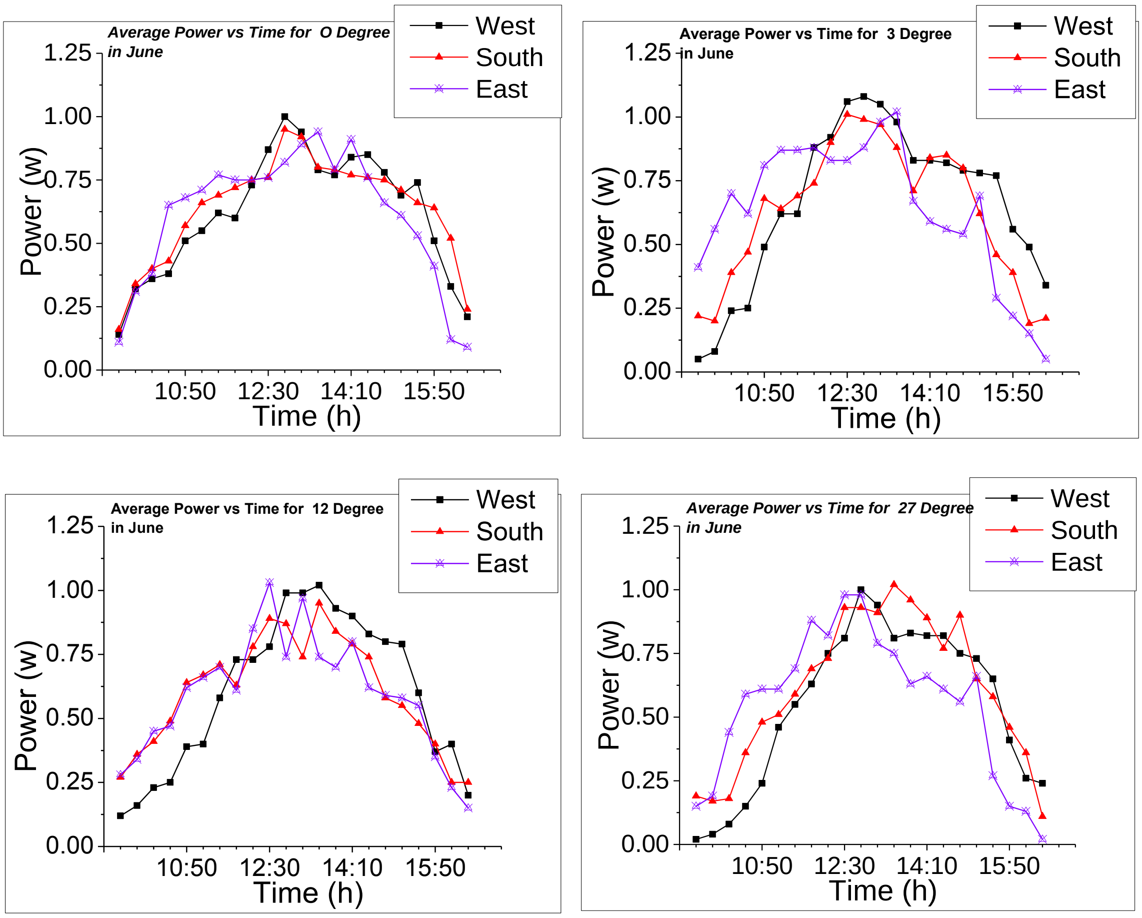

Fig. 6. Average output power versus time for West, South, and East of 0°, 3°. 12° and 27°

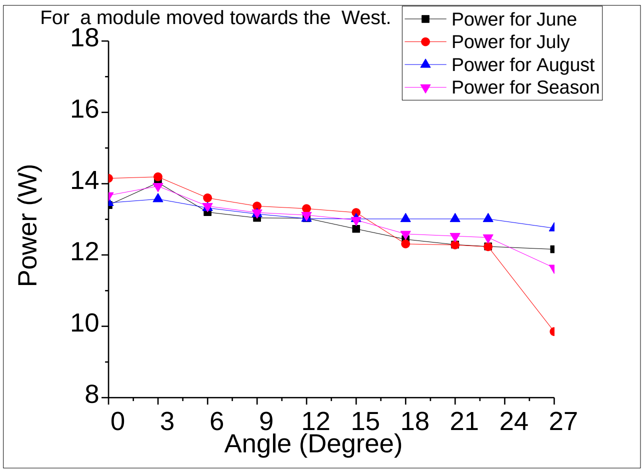

Fig. 7. Graph shows the optimum azimuth angle for east faced panel

3.2.2 Solar module moved towards the east

It is clear that in Table 4 and in graph 7 a unique value exists for each month of the season for which the power is at the highest. So, the computed average output power were (14.53W, 14.47W, 13.57W and 14.19W) in June, July, August and season respectively with the corresponding azimuth angle of 3^0. Therefore, 3^0 is the optimum azimuth angle of solar panel.

3.3 Distribution of Solar Power

3.3.1 Daily distribution of solar power from optimum azimuth and tilt angle

Daily distribution of maximum solar power analysis was performed to decide the best east-west orientation angles that yield an extreme daily solar power. This was done by comparing the sum of solar powers of the three modules with three times the power of the south facing (middle module) (supposing all the three modules are on the same plane orientation).

As shown in Table 5 in June, three out of three days orienting azimuth angle different from 0° has yielded better than the power gained when all three panels are on the same plane. Similarly, in July the azimuth angle different from 0° has yielded better than the power obtained when all three modules are on the same plane. However, on August, two out of three days orienting to east and west at the angle different from 0° has yielded better than the power obtained when all the three panels are on the same plane.

West(W)+ South(S)+East(E) is the total average output power from East and west oriented panels added to the power of the south faced panel. And 3×South is three times the cumulative average generated solar power of fixed south faced panel, which is nearly the power gained if the three panels were adjusted on the same level with the equivalent tilt angle.

The daily distribution of solar power received by the three solar panels at the daily optimum tilt angles and azimuth angle indicate that difference in orientation of east and west panels from the middle (south faced) panel improved depend on the duration of time, solar power function during early morning and late afternoon. Commonly, there is no found high power output during rotating to east and west. The only variation happened during morning and afternoon, but, if it has taken the average it’s not significant relative to the middle one which was fixed at the common tilt angle. This is because the output voltage of the east/west orientation solar panel follows the voltage of the east solar panel in the morning and the voltage of the west panel in the afternoon. But, the only variation has on 0^o up to 3^o clockwise and counterclockwise.

3.3.2 Monthly and seasonal distribution of solar power

As shown in Table 6, in Jun, July, and August, two border panels at angles different from 0^o have yielded better than the power obtained when all the three modules are on the same plane, respectively. The maximum solar panel's output power varies with the azimuth angle to east and west orientation which is due to an asymmetric distribution of power before and after the midday. The maximum solar panel's output power varies with the azimuth angle to east and west orientation which is due to an asymmetric distribution of power before and after the midday. The solar power directly depends on orientation and tilt of the panels, to determine the seasonal average power from the panels, optimum tilt and azimuth of solar photovoltaic arrays in a particular period.

Table 4. Computed total average output power for west faced in three selected days of each month

Azimuth angle (Degree)	Computed total average generated power (W)			
	June	**July**	**August**	**Season**
0	13.55	14.13	13.46	13.71
3	14.53	14.47	13.57	14.19
6	13.38	13.69	13.32	13.46
9	13.21	13.26	13.15	13.21
12	13.18	13.08	13.02	13.09
15	12.98	12.82	13.01	12.94
18	12.47	12.74	13.01	12.74
21	12.46	12.22	12.97	12.55
24	12.25	11.47	12.23	11.98
27	12.02	8.73	12.11	10.95

Table 5. The tilt and Orientation angles for the daily solar powers were obtained in June, July and August.

Direction	Month	June (4^o Tilt)			July(4^o Tilt)			August(2^o Tilt)		
	Date	**16/06/17**	**17/06/17**	**20/06/17**	**16/07/17**	**17/07/17**	**20/07/17**	**17/08/17**	**19/08/17**	**20/08/17**
West	Orientation angle(Degree)	3	3	3	3	9	3	0	3	18
	Total average power(W)	13.74	14.14	16.54	15.61	17.74	16.65	15.17	16.67	15.80
South	Orientation angle (Degree)	0	0	0	0	0	0	0	0	0
(Middle)	Total average power(W)	12.71	12.88	15.36	15.62	12.33	14.22	14.18	12.99	13.84
East	Orientation angle(Degree)	3	3	0	3	9	3	3	9	3
	Total average power(W)	13.71	14.16	16.47	16.55	13.62	16.77	16.11	14.98	15.28
	$W + S + E$	39.25	41.18	48.37	47.78	43.69	47.64	45.46	44.64	44.92
	$3\times South$ (Middle)	38.13	38.64	46.08	46.86	36.99	42.66	42.54	38.97	41.52

Table 5. Seasonal tilt and azimuth angles for average maximum powers were obtained

Orientation and energy		June(4^o)tilt angle	July(4^o)tilt angle	August(2^o)tilt angle	Season (average for 3 months)
East	Azimuths angle[^{o}]	3	3	3	3
	Average power(W)	14.03	14.19	13.57	13.93
West	Azimuths angle [^{o}]	3	3	3	3
	Average power(W)	14.53	14.47	13.57	14.19
South	Azimuths angle [^{o}]	0	0	0	0
	Average power(W)	13.69	13.68	13.46	13.66

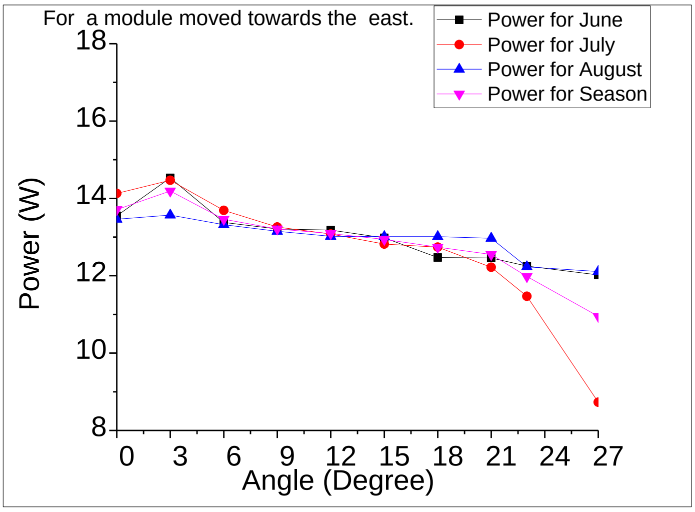

Fig. 8. Graph shows the optimum azimuth angle for west faced panel

The result described in Table 6 comparing in which way the azimuth angle moved to obtaining maximum energy was with relatively the middle one is very small. Furthermore, the solar panel moved towards the west with 3^o azimuth angle from the middle is 2.484% of power increased for the month of June, 3.728% and 0.817% for the month of July and August respectively. For the similar fashion, the panel that moved towards the east with azimuth angle 3^o from the middle increased 6.136% for the month of June, 5.775 % for the month of July and 0.817 % for the month of August. In the summer season, the solar power output could be maximized for a surface with a tilt angle of 4^o and oriented 0^o up to 3^o (clockwise and counterclockwise). When the optimum orientation and tilt for this season is considered, it increases the solar power output by 1.977% for east orientation and 3.880% for west orientation as compared with middle fixed solar panel's average output power. Therefore, to increase the efficiency of solar panel , the solar panel should be designed such that the angle of tilt can easily be changed at least on a seasonal basis, if not monthly and east-west orientation of solar panels in every month for this season if not daily.

4. CONCLUSION

The conclusion of this study can be described as follow:

1. The capacity of solar PV to generate maximum power depends by the orientation angles.
2. The optimum tilt angle of the solar power capacity is 4^0 with the increment of 1.56% as compared to solar power at 0^o tilt for a season.
3. The optimum azimuth angle of the solar power capacity is 3^0 with the increment of 1.977% for east and 3.880% for west orientation as compared with middle solar panel which is at the optimum tilt angle.

Therefore, this experimental study recommended that,

- ✓ To increase the efficiency of solar power, the solar panel should be designed such that the angle of tilt can easily be changed at least on a seasonal basis, if not monthly and east-west orientation of solar panels in every month for summer season if not daily.
- ✓ Anyone who is interested to use solar power from this geographical location, the solar panel should be adjusted at the optimum tilt of 4^o with south facing and azimuth of 3^o east-west, from the middle south faced at optimum tilt angle solar panel in the summer season.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/71993