Eng. &Tech.Journal, Vol. 32,Part (B), No.3, 2014

The 4th International scientific Conference on Nanotechnology& Advanced Materials & Their Applications (ICNAMA 2013)3-4 Nov, 2013

Determining Tilt Angle for Fixed Solar Panel Tosites of Iraq's Provinces by Using the Programs on NASA and Google Earth Websites

Imad Jawad Khadim
Ministry of Science and Technology / Baghdad
Email:imad_jk@yahoo.com
Emad Jaleel Mahdi
Ministry of Science and Technology / Baghdad
Ali Hussian Ubaid
Ministry of Science and Technology / Baghdad

ABSTRACT
The amount of generated electricity by photovoltaic fixed panels depend on tilt angles so must be identified correctly and accurately to increase the rates of solar radiation falling on them in this research were the optimal tilt angle of solar panels on locations of all Iraq provinces monthly and annually by locating a accurate GPS location depending on Google Earth program and then determining the values of the optimum tilt angles using the program in the NASA website. Has been found that the optimal tilt angle range between 28.3 for the province of Basrah as a minimum tilt angle with the horizon and 34.5 for the province of Dohuk as highest tilt angle with the horizon. Has been shown that the difference between the inclination angles optimal annually to Iraq's provinces on the horizon for the solar panels and between latitudes for those provinces almost invariably ranging from 2 to 3 degrees. It was noted that the difference between the monthly optimal tilt angles of provinces is ranging from 1 to 8 degrees.

تحديد زوايا ميل الألواح الشمسية الثابتة لمواقع محافظات العراق باستخدام برامج على موقع وكالة ناسا وGoogle earth

الخلاصة
يعتمد مقدار الطاقة الكهربائية المنتجة من ألواح الخلايا الشمسية الثابتة بشكل كبير على زوايا ميلها مع الأفق لذلك يجب تحديدها بشكل صحيح ودقيق لزيادة معدلات الإشعاع الشمسي الساقط عليها وفي هذا البحث تم تحديد زوايا ميل الألواح الشمسية المثلى لمواقع محافظات كافة العراق شهريا وسنويا من خلال تحديد مواقعها بشكل دقيق اعتمادا على برنامج Google earth وثم تحديد قيم زاويا الميل المثلى باستخدام برنامج في موقع وكالة ناسا وقد وجد أنها تتراوح بين زاوية ميل مع الأفق 28,3 لمحافظة البصرة كأدنى زاوية ميل مع الأفق و34,5 لمحافظة دهوك كأعلى زاوية ميل مع الأفق وقد تبين إن الفرق بين زوايا الميل المثلى سنويا لمحافظات العراق عن الأفق للألواح الشمسية وبين خطوط العرض لتلك المحافظات ثابت تقريبا ويتراوح بين 2 إلى 3 درجة ولوحظ إن الفرق بين زوايا الميل المثلى شهريا للمحافظات يتراوح بين قيم 1° الى 8° درجة خلال السنة.

https://doi.org/10.30684/etj.32.3B.11
2412-0758/University of Technology-Iraq, Baghdad, Iraq

INTRODUCTION

The sun is a sphere of intensely hot gaseous matter with a diameter of 1.39 × 109m.In effect the sun is a continuous fusion reactor , hydrogen is turned into helium. The sun's total energy output is 3.8 □1020MW which is equ to 63MW/m2 of the sun's surface. This energy radiates outwards in all directions. Only a tiny fraction, 1.7 □1014kW of the total radiation emitted is intercepted by the earth [1]. However, even with this small fraction it is estimated that 30 min of solar radiation falling on earth is equal to the world energy demand for one year.The performance of a solar PV array is highly influenced by its angle of tilt with the horizontal. This is due to the facts that tilt angle change the solar radiation reaching the surface of the PV array, the tilt angle, defined as the angle of PV arrays with respect to horizontal, is a dominant parameter affecting the collectible radiation of a fixed PV array. In general, the optimal tilt angle of a fixed PV array is related to the local climatic condition, geographic latitude and the period of its use. Hence, different places will have different optimal tilt angles for a yearly-used solar PV array. To date, a number of studies on the optimal tilt angle of PV arrays have beenconducted [1–7], and a lot of empirical correlations for estimating the optimal tilt-angle are available in the literature [2, 5–7]. It is reported in the literature that the optimum orientation of the PV array should be directly towards the equator, facing south in the northern hemisphere and the optimum tilt angle depends only on the latitude. For example, Lunde [6] and Garge [9] $\beta opt = \pm15°$, Duffie and Beckman [10] suggestedβ opt = (φ + 15°) ±15 °, and Heywood [6] concluded that β opt = (φ + 15°), where φ latitude of the location.In a PV system, the PV cell material contributes about 50% of the total cost. Thus, effective ways to lower the cost of electricity generated by a PV system are toreduce the use of solar cells for given power demand, including use of optical concentrators and thinner wafer, thin film solar cell technologies, improving photovoltaic conversion efficiency as possible and continuous tracking of the sun[4-7]. However, most methods to reduce the cost of electricity generated by PV systems would either make system more complex or increase the production cost of the system. To maximize energy collection, solar modules are usually oriented toward the equator with a yearly optimal tilt-angle from the horizon which depends on climatic conditions and site latitude [2-3]. A study performed by Morcos showed that changing collectors' azimuth and tilt angles daily to their optimum values in Egypt achieved an annual gain in total solar radiation of 29.2% more than a fixed collector with tilt angle equal to its geographic latitude[4], where the solar radiation analyzed is predicted by an empirical model applicable for clear sky situation. However, daily and monthly adjustment of tilt-angles is troublesome in practical application due to frequent adjustment and complex structure of frames which support solar panels. Seasonal adjustment of tilt-angle may be a simplest way and easier to be implemented in practice. In this mode of tilt-angle adjustment, the tilt-angle of solar panels is only changed 4 times per year with the tilt angle being site latitude (φ) around the equinoxes and ($\varphi \pm \alpha$) around the solstices (α is the value of tilt-angle adjustment from the site latitude) .The amount of solar radiation incident on a tilted module surface is the component of the incident solar radiation which is perpendicular to the module surface. The following figure shows how to calculate the radiation incident on a tilted surface (Smodule) given either the solar radiation measured on horizontal surface (Shoriz) or the solar radiation measured perpendicular to the sun (Sincident) as in Figure(1).

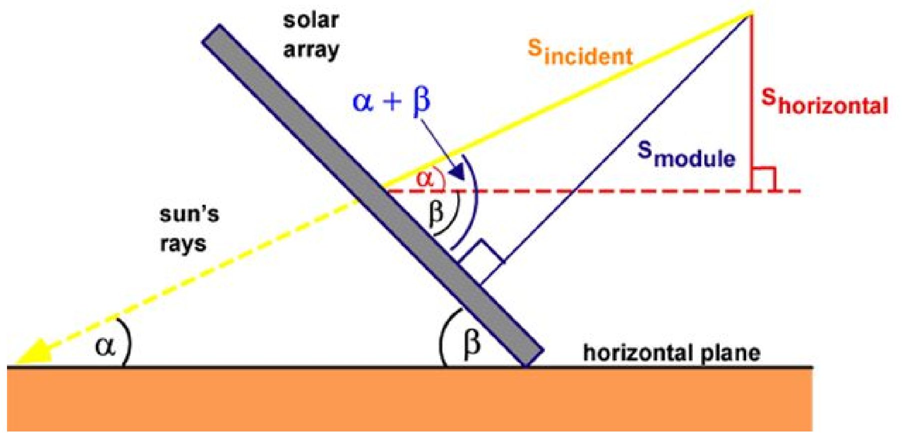

Figure (1) Tilting the module to the incoming light reduces the module output.

The equations (1, 2) relating S_{module}, S_{horiz} and $S_{incident}$ are [8]:

$$S_{horizontal} = S_{incident} \sin \alpha \quad \dots (1)$$

$$S_{module} = S_{incident} \sin(\alpha + \beta) \quad \dots (2)$$

Where
α: is the elevation angle; and
β: is the tilt angle of the module measured from the horizontal.
The elevation angleα is given by:

$$\alpha = 90 - \phi + \delta \quad \dots..(3)$$

Where φ is the latitude; and
δ is the declination angle previously given as:

$$\delta = 23.45^{\circ} \sin\left[\frac{360}{365}(284 + d)\right] \quad \dots (4)$$

Where d is the day of the year. Note that from simple math (284+d) is equivalent to (d-81). Two equations are used interchangeably in literature [8].
From these equations a (1) and (2) we can be determined as:

$$S_{module} = \frac{S_{horizontal}\sin(\alpha+\beta)}{\sin\alpha} \qquad \dots (5)$$

THE METHOD

By using Google earth prgram the GPS for two sites of Iraq's provinces as shown in Figure(2) which is a geographical program created by keyhole company owned by google company . The program draw the earth map depending on satellite images [7].

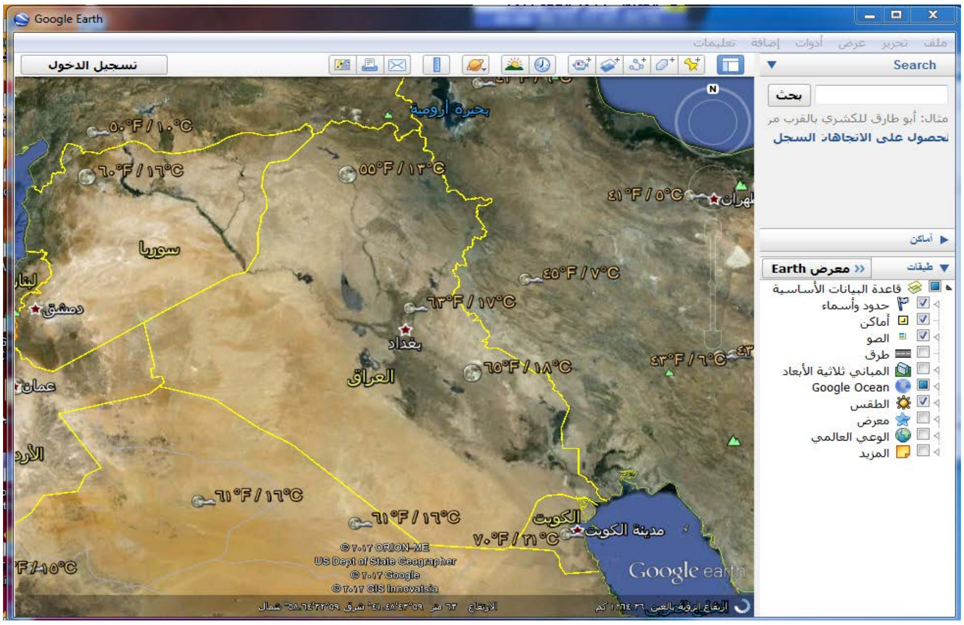

Figure (2) User interface for Google earth program.

Depending on NASA program to determine the optimum the tilts angles for of Iraq's provinces as in Figure (3) [9].

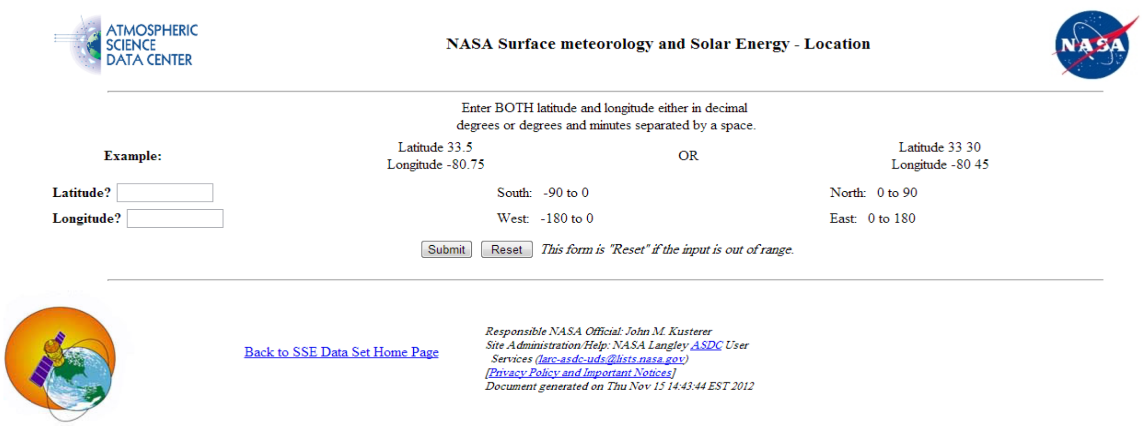

Figure (3) User interface for NASA program [9].

RESULTS AND DISCUSSION

By using NASA program the yearly optimum tilts angles for all sites of Iraq's provinces has been determined as seen in the following Table:-

Table (1) Yearly optimum tilts angles for all sites of Iraq's provinces with latitudes values.

latitudes	yearly optimum tilts angles	provinces
30.519	28.3	Basra
31.05	28.8	Alnasirya
31.31	28.9	Sumwaa
32	29.6	Najif
31.98	29.6	Dewania
31.86	29.8	Messan
32.466	30	Babil
32.6	30.1	Karbla
32.5	30.2	Kut
32.55	30.2	Alanbar
33.325	31.2	Baghdad
33.76	31.3	Deyala
34.6	31.7	Tikrit
36.18	32.2	Eribil
36.33	32.6	Mosul
35.46	32.9	Kirkuk
35.53	33.1	Sulamania
37.13	34.5	Dahok

As seen in the Figure (4) the difference between yearly optimum tilt angle and latitudes is approximately between 2 to 3 degree.

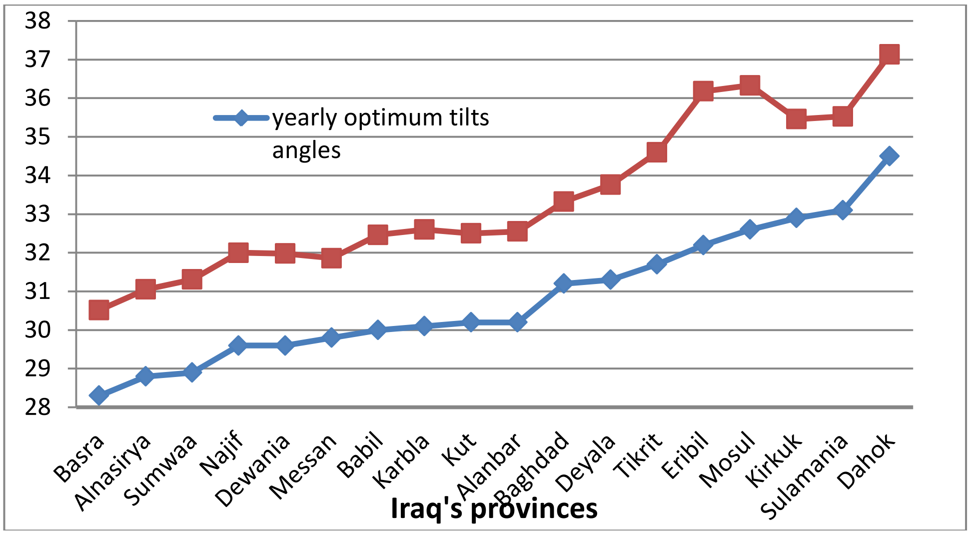

Figure (4) Yearly optimum tilt angle and latitudes.

A linear relationship interpolated between yearly optimum tilt angle and latitudes from Figure (4) which was y=0.17x-3.11 (9) Its represent the the difference between yearly optimum tilt angle and latitudes as seen in the Figure (5) the deviation from linear relationship increase with increasing the latitude that because of the fact [4] that, the diffuse radiation always has its maximum value in a horizontal installation. However, the maximum beam radiation is achieved at an installation angle close to the latitude angle. Since the combination of these two component screates the dominant part of the total radiation, it makes the optimum angle smaller than the latitude Besides, for higher latitudes the difference between these two angles becomes high enough to cause a larger discrepancy between the value of the optimum angle and the location’s latitude. It is possible to claim that for small values of latitude, the optimum angle is close to the location’s latitude, while for the higher ones the optimum angle is smaller.

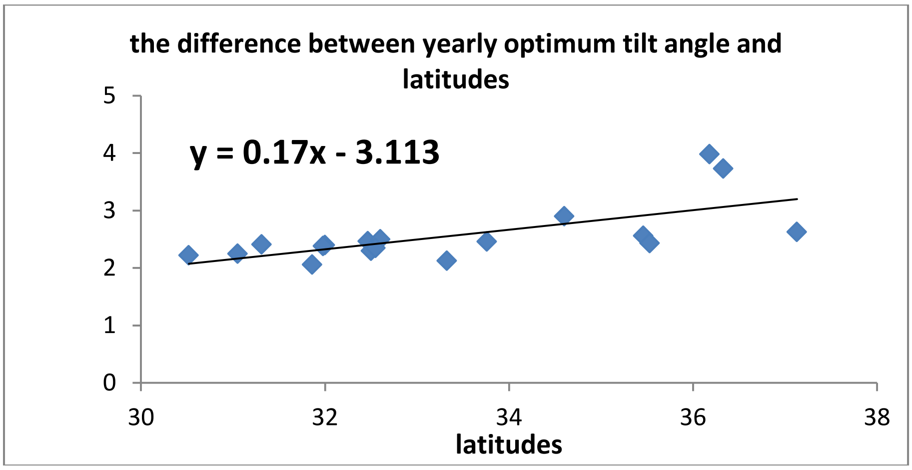

Figure (5) Linear relationship between yearly optimum tilt angle and latitudes.

And also monthly optimum tilt angles has been determined for for all sites of Iraq's provinces as in Table (2).

Table (2) Monthly optimum tilt angles for all sites of Iraq's provinces.

Dahok	Sulamania	Kirkuk	Mosul	Eribil	Tikrit	Deyala	Baghdad	Alanbar	Kut	Karbla	Babil	Messan	Dewania	Najif	Sumwaa	Alnasirya	Basra	months
61	60	60	59	58	59	58	58	56	57	56	56	57	55	56	55	55	55	1
50	51	51	49	48	50	50	51	49	50	50	50	50	48	49	48	49	48	2
39	38	38	37	36	37	37	37	36	35	35	35	35	35	34	34	33	33	3
21	20	20	20	20	19	20	19	19	19	19	19	18	19	18	17	17	17	4
9	7	7	8	8	6	6	5	5	4	5	4	4	4	4	3	3	3	5
3	2	2	2	2	1	0	0	0	0	0	0	0	0	0	0	0	0	6
6	4	4	5	5	3	2	2	1	1	1	1	1	1	1	0	0	0	7
17	15	15	16	15	14	13	13	12	12	12	12	11	12	12	11	11	10	8
35	33	32	32	32	32	31	30	30	29	29	29	28	29	29	28	28	27	9
50	48	47	47	47	45	45	46	45	44	44	44	44	44	43	43	43	41	10
60	58	58	57	56	55	55	55	53	54	53	53	53	52	53	52	52	51	11
64	63	63	61	61	61	60	60	58	59	59	59	59	58	58	58	57	57	12
34.5	33.1	32.9	32.6	32.2	31.7	31.3	31.2	30.2	30.2	30.1	30	29.8	29.6	29.6	28.9	28.8	28.3	yearly optimum tilts angles

Figure (6) represents the monthly optimum angle for angles for all sites of Iraq's provinces we noted that the differences between them round between 8 and 1 degree within the year.

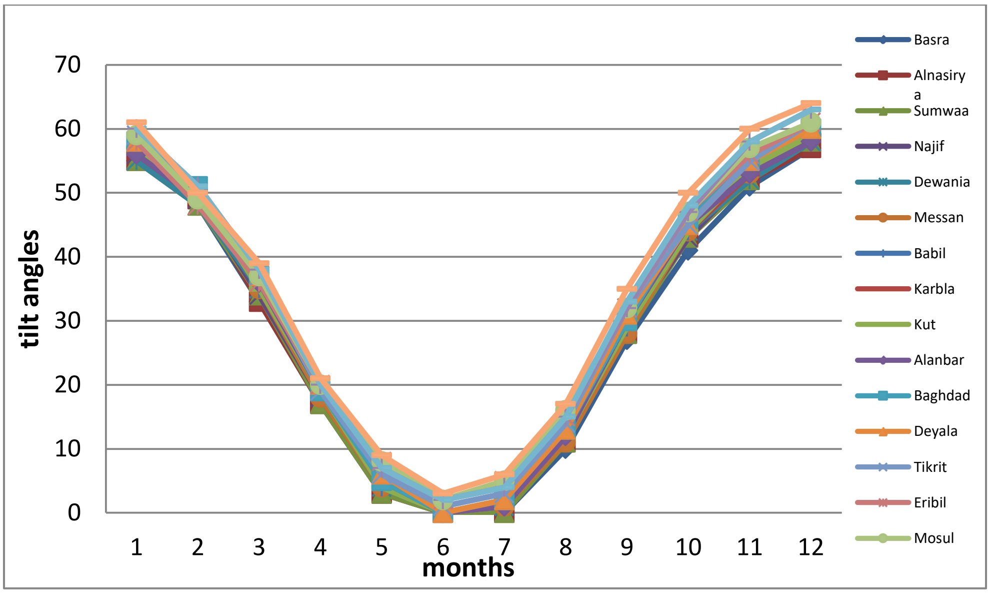

Figure (6) Monthly optimum angle for angles for all sites of Iraq's provinces.

As an example on the effect of tilt angle for fixed solar panels on the incident solar radiation we see the monthly average solar radiation for tilts angles (0, 18, 33, 48, 90) degree for Baghdad city from NASA website in Table(3).

Table (3) Maximum Radiation Incident On An Equator-pointed Tilted Surface (kWh/m^2/day).

Lat 33.325 Lon 44.422	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
SSE MAX	3.27	4.66	5.90	5.96	6.95	8.49	7.68	7.36	6.15	4.6 7	3.40	2.86	5.61
K	0.60	0.68	0.69	0.58	0.62	0.73	0.68	0.70	0.68	0.64	0.59	0.57	0.65
Diffuse	0.82	0.83	1.11	1.86	2.00	1.52	1.78	1.44	1.27	1.09	0.91	0.80	1.29
Direct	5.32	6.87	7.34	6.00	6.91	9.02	7.89	7.99	7.25	6.19	5.21	4.81	6.73
Tilt 0	3.22	4.62	5.83	5.82	6.92	8.44	7.64	7.33	6.06	4.63	3.33	2.83	5.56
Tilt 18	4.31	5.87	6.69	6.07	6.81	8.08	7.41	7.46	6.69	5.60	4.33	3.85	6.10
Tilt 33	4.96	6.54	6.99	5.94	6.33	7.29	6.79	7.11	6.81	6.06	4.90	4.47	6.18
Tilt 48	5.32	6.83	6.89	5.50	5.54	6.16	5.82	6.40	6.54	6.18	5.19	4.83	5.93
Tilt 90	4.66	5.51	4.65	2.99	2.51	2.27	2.39	3.06	4.04	4.71	4.42	4.33	3.78
OPT	5.38	6.84	7.00	6.07	6.94	8.44	7.64	7.48	6.81	6.19	5.22	4.92	6.58
OPT ANG	58.0	51.0	37.0	19.0	5.00	0.00	2.00	13.0	30.0	46.0	55.0	60.0	31.2

CONCLUSIONS

The amount of generated electricity by photovoltaic fixed panels depend on tilt angles so must be identified correctly and accurately to increase the rates of solar radiation. Has been shown that the difference between the inclination angles optimal annually to Iraq's provinces on the horizon for the solar panels and between latitudes for those provinces almost invariably ranging from 2 to 3 degrees. was noted that the difference between the monthly optimal tilt angles of provinces is ranging from 1 to 8 degrees which was applied in Baghdad where the tilt angle is 31 degree maximize the yearly output power for solar panel. the deviation from linear relationship increase with increasing the latitude that because the diffuse radiation always has its maximum value in a horizontal installation and the diffuse radiation increase with latitude angle so it is possible to claim that for small values of latitude, the optimum angle is close to the location’s latitude, while for the higher ones the optimum angle is smaller.

REFERENCES

[1]. Mahler, E.D. P.L. Zervas, 2010, Determination of the optical tilt angle and orientation for solar photovoltaic arrays. Renewable Energy 35, 2468-2475.

[2].Jager-WaldauArnulf.PhotovoltaicandrenewableenergiesinEurope. Renewable and Sustain able Energy eviews 2007; 11, 1414-37.

[3].BadescuV.Simulation of solar cells utilization on the surface of Mars. Acta Astronautica1998; 43(9-10):443-53.

[4].Arbi Gharak hani Siraki, Pragasen Pillay, 2012. Study of optimum tilts angles for solar panels in different latitudes for urban applications. Solar energy 86, 1920 – 1928.

[5].Calabro` a, E., 2009. Determining optimum tilt angles of photovoltaic panels at typical north-tropical latitudes. J. Renew. Sust. Energy1.

[6].Chang, T.P., 2008. Study on the optimal tilt angle of solar collector according to different radiation types. Int. J. Appl. Sci. Eng. 6.

[7].Chen, Y., Lee, C., Wu, H., 2005. Calculation of the optimum installation angle for fixed solar-cell panels based on the genetic algorithm and the simulated-annealing method. IEEE Trans. Energy Convers. 20, 467– 473.

[8].Robert F., Majid G., Alma C., 2010. Renewable Energy and the Environment. p(7-49). CRC Press, Taylor & Francis Group. Boca Raton.

[9]. NASA Langley Research Center, Atmospheric Science Data Center. Website (https://eosweb.larc.nasa.gov/).