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ORIGINAL

Evaluating and Analyzing the Transposition Factor in Al- Musayyib Technical College to Setting the Optimal Tilt Angle for Fixed and Seasonal Orientation

Evaluación y análisis del factor de transposición en la Escuela Técnica Superior Al Musayyib para establecer el ángulo de inclinación óptimo para la orientación fija y estacional

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ABSTRACT

The transposition factor (TF) enhances the photovoltaic (PV) systems' capacity to generate output power. The observed phenomenon denotes the alteration in power production resulting from the inclination of the collector plane. The objective of this study is to assess and compare the effects of two different types of orientation, fixed titled plane and seasonal tilt adjustment, on the power output of a photovoltaic system located in the electrical engineering technologies department at Al- Musayyib Technical College (MTC) in Iraq. The specific coordinates of the location are latitude 32° 46′ 59.99″ N and longitude 44° 19′ 0.01 E . The simulation will be conducted using the Perez model in PVSYST software, focusing on a standalone system with a power capacity of 3000 Wp. The results that were displayed are dependent on the highest (TF), the optimal tilt angle for a fixed tilted plane is 28º, and for seasonal tilt adjustment is (12º in summer and 50º in winter). In addition, the results showed that applying the seasonal tilt adjustment was preferable to using a fixed titled plane in this location to gain the maximum amount of system production power while maintaining a low cost.

Keywords: Transposition Factor; Seasonal Adjustment Orientation of PV System; Al-Musayyib Technical College Optimum Orientation; Fixed Titled Plane Orientation.

RESUMEN

El factor de transposición (FT) aumenta la capacidad de los sistemas fotovoltaicos (FV) para generar potencia de salida. El fenómeno observado denota la alteración en la producción de potencia resultante de la inclinación del plano de colectores. El objetivo de este estudio es evaluar y comparar los efectos de dos tipos diferentes de orientación, plano fijo inclinado y ajuste estacional de la inclinación, sobre la producción de potencia de un sistema fotovoltaico situado en el departamento de tecnologías de ingeniería eléctrica del Al- Musayyib Technical College (MTC) de Iraq. Las coordenadas específicas de la ubicación son latitud 32° 46′ 59,99″ N y longitud 44° 19′ 0,01 E . La simulación se llevará a cabo utilizando el modelo Pérez en el software PVSYST, centrándose en un sistema autónomo con una capacidad de potencia de 3000 Wp. Los resultados que se mostraron dependen de la mayor (TF), el ángulo de inclinación óptimo para un plano inclinado fijo es 28º, y para el ajuste de inclinación estacional es (12o en verano y 50o en invierno),. Además, los resultados mostraron que la aplicación del ajuste estacional de la inclinación era preferible a la utilización de un plano inclinado fijo en esta ubicación para obtener la máxima cantidad de potencia de producción del sistema manteniendo un coste bajo.

Palabras clave: Factor de Transposición; Ajuste Estacional de la Orientación del Sistema Fotovoltaico; Orientación Óptima del Colegio Técnico Al-Musayyib; Orientación del Plano Titulado Fijo.

INTRODUCTION

The energy sources of the contemporary world are currently shifting from conventional to clean and renewable. Solar energy has been widely acknowledged as a highly promising and reliable renewable energy source. due to its sustainability and accessibility in nearly every part of the globe. Photovoltaic (PV) technology, which has advanced quickly, is one possible use of solar energy. Using solar PV technology is one of the finest ways to use the sun's energy.(1) The yearly solar energy that reaches Earth's surface is 1.5×1018 kWh,(2) of which 30 % is reflected back into space and the remainder is absorbed by clouds, land masses, and seas. Iraq is situated in the Middle East, specifically between latitudes 29° 5' and 37° 22' N and longitudes 38° 45' and 48° 45' E. September is predicted to have the most significant solar radiation at 6790 kWh/m2, while December has the lowest at 1660 kWh/m2.(3) Iraq is thus ideally situated for solar energy potential.

PV panel orientation and tilting angle have a significant influence on their performance. The tilt angle and direction can alter how much solar radiation the panel absorbs. In the morning and afternoon, the rays of sun's fall at a narrow angle. At noon, they fall at a high angle. Thus, PV tilt angles vary monthly, seasonally, and annually based on the location.(4) Mathematical computations and experimental data should be used to support monthly and seasonal variations in the tilt angles of the panels. Numerous investigations revealed that the Optimal tilt angle is dependent on the days of the year, solar declination angle, and latitude angle (λ).(5) To get more energy, solar panels are usually angled towards the equator. The optimal tilt angle from the sky for each year depends on the location's latitude and weather conditions.(6,7) An yearly increase in the total solar irradiation of 29,2 % was achieved in Egypt by adjusting collectors' azimuth and tilt angles to their optimal values on a daily basis, according to a study conducted by Morcos. This was in comparison to a fixed collector whose tilt angle matched its geographic latitude,(8) evacuated tube solar water heaters,(9,10) hybrid power systems,(11,12) PV generation(13,14) and solar cookers.(13)

According to the literature, it is stated that in the northern hemisphere, the most favorable direction for orientation is towards the south, and the most favorable degree of inclination relies only on the latitude. Researchers have not provided a specific value for the ideal tilt angle. For instance, Lunde(15) and Garge(16) $\beta_{opt}=\emptyset\pm15°$, Heywood(17) reached the conclusion that $\beta_{opt}=\emptyset-10°$ while according to Duffie et al.(18), the recommended equation $\beta_{opt}=(\emptyset+15°)\pm15°$ incorporates the latitude of the place $\emptyset$, winter and summer are indicated by plus and minus signs. Theoretical models for β_{opt} were proposed by Lewis(19), who examined two distinct models for β_{opt} that correspond to, as stated in $\beta_{opt}=\emptyset\pm8°$. El-Kassaby et al.(20) and Bari et al.(21) developed the analytical equation to determine the ideal daily angle at every latitude. They demonstrated that the largest discrepancy between the calculated value for β_{opt} using the analytical equation and the experimental value for β_{opt} did not surpass 3%. Furthermore, they determined that the most favorable inclination angle for each given time frame could be derived by integrating the analytical equation across the specified duration. El-Kassaby et al.(20) calculated the most favorable tilt and surface azimuth angles for an absorber plate that is protected by either one or two glass coverings. He stated that the utilization of two glass coverings instead of a single one has negligible impact on the value of β_{opt}. Prior research does not provide a specific recommendation for the tilt angle.

Sun-tracking devices can be used to receive the most efficient solar energy yield. Many studies demonstrate that, in comparison to fixed systems, tracking systems provide for a considerable amount of solar energy. Comparing tracking systems with fixed systems,(22) discovered that the total daily energy collected increased by almost 43,87 %. In Mousazadeh et al.(26), an extensive analysis of the energy gain of several trackers is conducted.(23) The authors of that research report a 10–100 % increase in solar energy captured using tracking systems, based on various time periods and geographic circumstances. According to Tomson(24), employing a two-positional tracking system that places collectors in the morning and afternoon can increase seasonal energy yield by 10 % to 20 %. Using a single-axis tracking system, Abidin et al.(25) discovered significant gains of 51,4 %, 28,5 %, and 18,7 % from the extraterrestrial, expected, and observed radiations, respectively. Sun-tracking systems, however, are highly costly, energy-intensive, and should not be used with small solar panels.(26) Setting up the collection on the optimal angle is the other way to get more energy. Many studies have been done around the world to find the best tilt position for solar collectors, Izmir in Turkey,(27) Sanliurfa, Turkey,(28) Dhaka,(29) 30 cities in China,(30) Madinah, Saudi Arabia,(1) Jordan,(31) Helwan, Egypt, Brunei Darussalam,(1) Syria,(32) Cyprus[1], Burgos, Spain,[33] and many more.

In recent years, a multitude of research projects have concentrated their attention on optimising the tilt and orientation angles in certain locations. Benghanem[34] determined the most favorable inclination angle for the solar panel in Madinah, Saudi Arabia by analyzing past data. The second-order polynomial equations were fitted to describe the graphs of total solar irradiation versus tilt angle for each month. To find the optimal tilt angle, the polynomial formulas were differentiated and set equal to zero. Kacira et al.[35] determined the most favorable inclination angle for Sanliurfa, Turkey and implemented it in a sun tracker that operates on two axes. The performance of the tracking photovoltaic (PV) module was compared to that of an identical PV module with zero tilt angles. In 2009 a study determined the ideal tilt angle for solar panels in Syria by considering the amount of extraterrestrial radiation that falls on a tilted surface at any given moment. conducted a study in Dhaka to determine the optimal tilt angle for solar panels. This was accomplished by employing three solar models.

In this study to increase solar radiation falling on the solar complex and to obtain the maximum energy production, the solar array must be at a correct angle. By designing and simulation, an independent system using Perez model on PVsyst 7.2 software to obtain the value of the yearly and seasonal optimal angle (summer and winter) depend on analysis of transposition factor in the (MTC).

Transposition factor

The generation of energy of PV arrays is influenced by the transposition factor, which is determined by the tilt and azimuth angles. In orientation optimization, a transposition factor, which is defined as a ratio of incident radiation on the plane to horizontal irradiance, is crucial.[36] The transposition factor quantifies the irradiation gain or loss caused by a collector plane that is tilted. The direction of incident irradiation on the surface of the photovoltaic module is directly proportional to the highest amount of the transposition factor. For example, the optimizing tool of PVsyst, a software program designed for the modeling and analysis of PV systems,[7] incorporates transposition factor calculations through the computation of 475 yearly transposition factor calculations. Utilizing this instrument, optimal position of PV systems can be ascertained.

$$TF = \frac{Global\ irradiation\ on\ tilted\ plane}{global\ irradiation\ on\ horizontal\ plane} = \frac{G_t}{G} \qquad (1)$$

The concept of transposition factor refers to a variable or parameter that influences the rearrangement or reordering of elements within a given system the graphs produced in PVsyst, as exemplified in figure 1, can be utilized to visually depict the transposition factors associated with various combinations of tilt and azimuth during an entire year's cycle. The optimal orientation is indicate by a black dot, which represents the ideal combination of the tilt and azimuth. Subsequent contours depict areas with equal transposition factors, delineated by iso-transposition curves. The monthly tables, shown in table 1, present the fluctuations of transposition factors across different tilts and azimuth combinations for the entirety of a year.

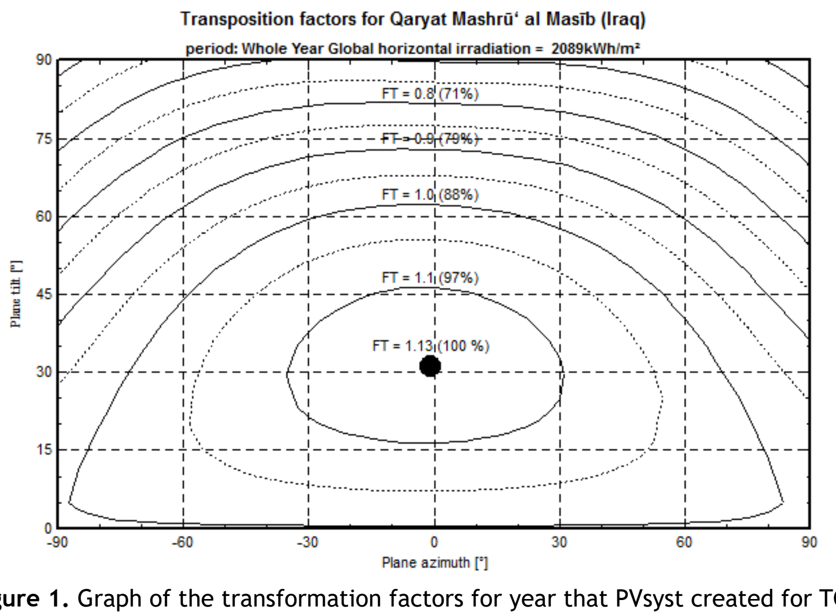

Figure 1. Graph of the transformation factors for year that PVsyst created for TCM

In order to optimize the annual energy yield, the utilization of graphs and tables is recommended. Conversely, systems that rely on timing or season of use can determine the most favorable orientations by referring to the

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monthly tables. Figure 2 and figure 3 shows the transposition factors for each of the tilt and azimuth angle combination that includes a summer and winter cycle.

Table 1. Monthly transposition factors for (MTC) (Iraq) with different tilt and azimuth angle

Tilt	Azimuth	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year
0°	+/- 0°	1	1	1	1	1	1	1	1	1	1	1	1	1
15°	+/- 0°	1,3	1,21	1,13	1,05	1	0,98	0,99	1,03	1,1	1,18	1,28	1,33	1,09
15°	+/- 30°	1,25	1,18	1,11	1,04	1	0,98	0,99	1,03	1,08	1,15	1,24	1,28	1,08
15°	+/- 60°	1,14	1,09	1,05	1,02	0,99	0,98	0,99	1,01	1,04	1,08	1,13	1,15	1,04
15°	+/- 90°	0,99	0,98	0,98	0,98	0,98	0,98	0,98	0,98	0,98	0,99	0,98	0,99	0,98
30°	+/- 0°	1,52	1,35	1,19	1,05	0,95	0,91	0,93	1,01	1,14	1,3	1,48	1,58	1,13
30°	+/- 30°	1,44	1,29	1,15	1,03	0,95	0,92	0,93	1	1,11	1,25	1,41	1,49	1,11
30°	+/- 60°	1,23	1,14	1,07	0,99	0,95	0,92	0,94	0,98	1,04	1,12	1,2	1,25	1,03
30°	+/- 90°	0,96	0,94	0,94	0,93	0,93	0,92	0,93	0,93	0,93	0,95	0,94	0,95	0,93
45°	+/- 0°	1,66	1,41	1,19	0,98	0,85	0,79	0,82	0,93	1,11	1,34	1,6	1,75	1,11
45°	+/- 30°	1,54	1,33	1,14	0,97	0,86	0,81	0,84	0,93	1,08	1,27	1,49	1,62	1,07
45°	+/- 60°	1,25	1,13	1,03	0,93	0,87	0,84	0,85	0,91	0,99	1,1	1,22	1,29	0,99
45°	+/- 90°	0,9	0,87	0,87	0,85	0,84	0,84	0,84	0,85	0,86	0,89	0,89	0,9	0,86
60°	+/- 0°	1,7	1,39	1,12	0,87	0,71	0,64	0,67	0,81	1,02	1,3	1,62	1,8	1,02
60°	+/- 30°	1,56	1,29	1,07	0,86	0,74	0,68	0,7	0,82	0,99	1,22	1,49	1,65	0,99
60°	+/- 60°	1,22	1,07	0,96	0,83	0,76	0,73	0,75	0,81	0,91	1,04	1,18	1,26	0,9
60°	+/- 90°	0,83	0,79	0,79	0,76	0,75	0,74	0,75	0,76	0,78	0,81	0,82	0,83	0,77
90°	+/- 0°	1,48	1,12	0,8	0,52	0,35	0,28	0,31	0,44	0,68	1,02	1,38	1,6	0,7
90°	+/- 30°	1,31	1,02	0,77	0,56	0,43	0,38	0,4	0,51	0,68	0,94	1,23	1,42	0,7
90°	+/- 60°	0,98	0,82	0,71	0,59	0,52	0,49	0,5	0,56	0,66	0,8	0,93	1,02	0,66
90°	+/- 90°	0,65	0,6	0,59	0,55	0,53	0,53	0,53	0,55	0,57	0,61	0,62	0,64	0,57

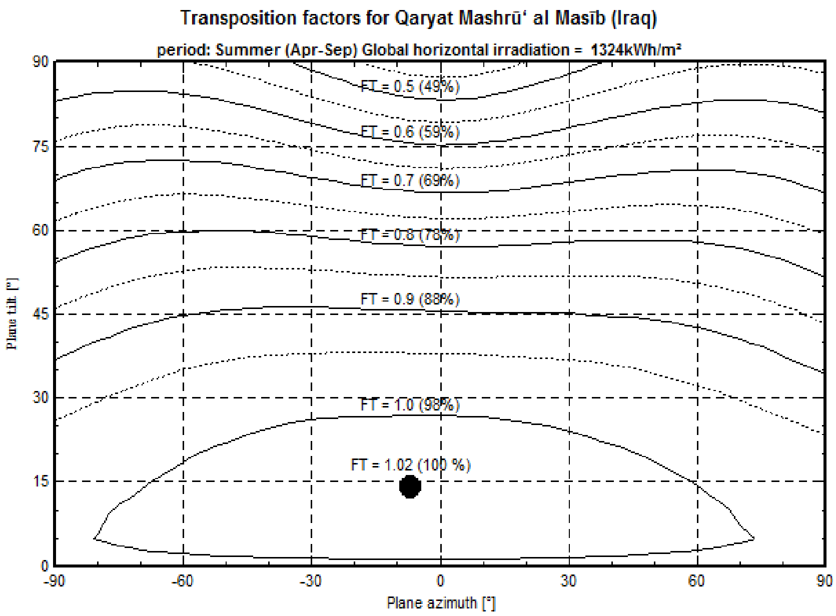

Figure 2. Graph of the transformation factors for summer that PVsyst created for TCM

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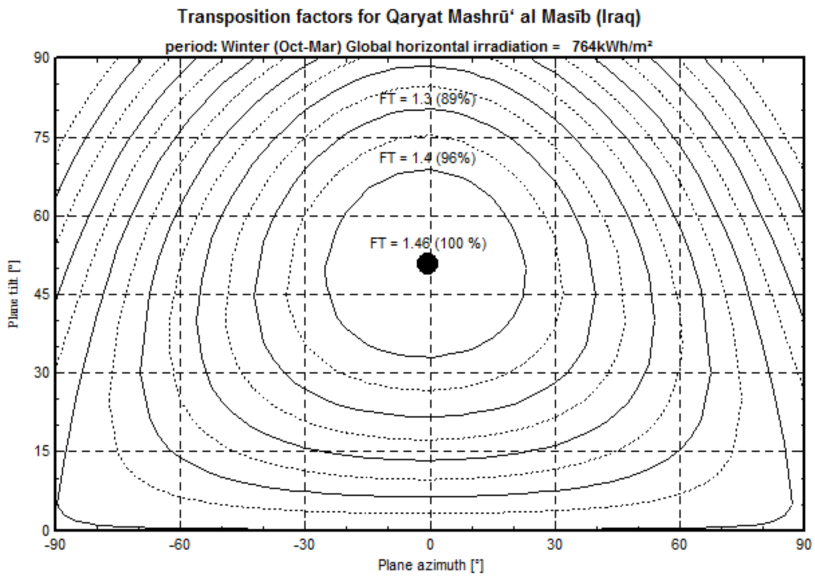

Figure 3. Graph of the transformation factors for winter that PVsyst created for TCM

In general, the total amount of solar irradiation incidence on photovoltaic (PV) panels is comprised of three components: the direct beam irradiation (G_{Bt}), the diffuse irradiation reflected from the ground (G_{Dt}), and the absorbed beam irradiation (G_{Gt}).

$$G_t = G_{Bt} + G_{Dt} + G_{Gt} \qquad (2)$$

The (Gt) radiation incidence on the tilted plane is calculated by decomposing the (G) monthly average horizontal plane incident (KWh/m2). Variations in tilt angles (β) affect (Gt) values. At the optimum tilt angle (β opt), the global beam on the tilted surface (Gt) is at its highest value. TF is greatest at this tilt angle.[37] According to equation (1).

METHOD

Simulation methodology

Step 1: set up the parameters for geographical sites

Table 2. geographical characteristics of the site

	GlobH (kWh/m²)	DiffH (kWh/m²)
Jan.	91,8	30,7
Feb.	109,5	33,6
Mar.	150,7	49
Apr.	171,9	58,8
May	209,9	64,2
June	238,2	53,7
July	228,5	59,8
Aug.	214,5	52,1
Sep.	174,6	43,8
Oct.	124	42,5
Nov.	88,5	33
Dec.	81,8	28,5
Year	1883,9	549,7

The PV Syst software version 7.2.2 was utilized in this study. The system is situated within the Electrical engineering technologies department in MTC region of Iraq, specifically positioned at a latitude of 32° 46′ 59,99″ N and a longitude of 44° 19′ 0,01 E. Furthermore, it is situated at an elevation of 27 meters. The software is utilized for acquiring the geographical characteristics of certain sites to enables the retrieval of monthly data on Global Horizontal Radiation (GHI or GlobHor) and monthly Diffuse Horizontal Radiation (DiffHor), as presented in table 2.

Step 2: settingof the fixed tilted optimum tilt angle

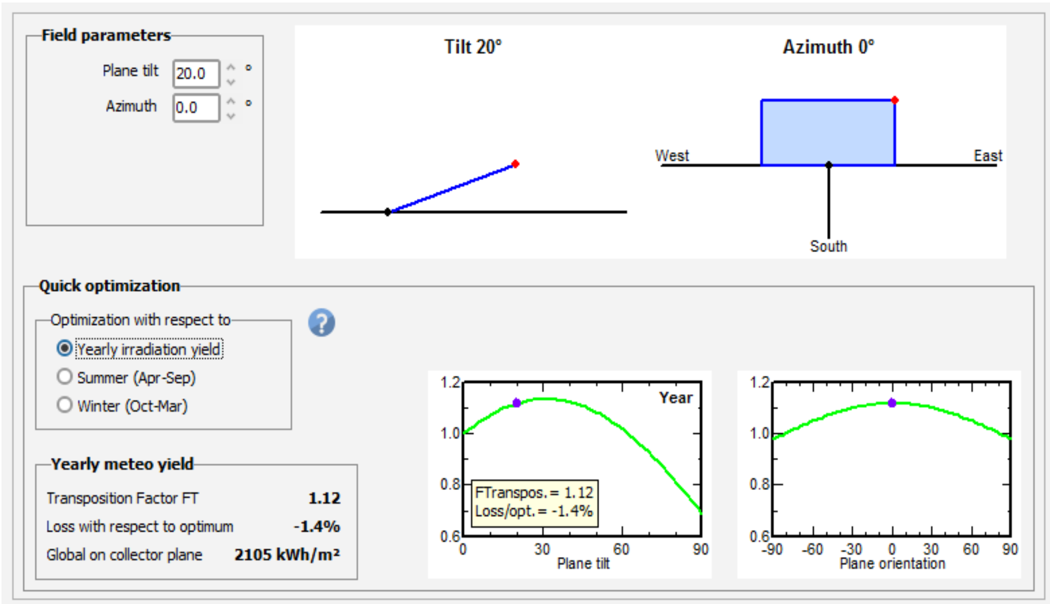

Figure 4. Tilt angle of the site

To obtain the optimum tilt angle in this site as in figure 1 depicts the various tilt and azimuth angles that can be used to maximize solar radiation received by PV panels and, in turn, system production power. In Iraq, fixed PV arrays must face south.

Step 3: loads information and energy use

As shown in figure 5 reveals that the daily energy consumption is 11010 Wh/day, and the total monthly power need is 330,0 kW/mth.

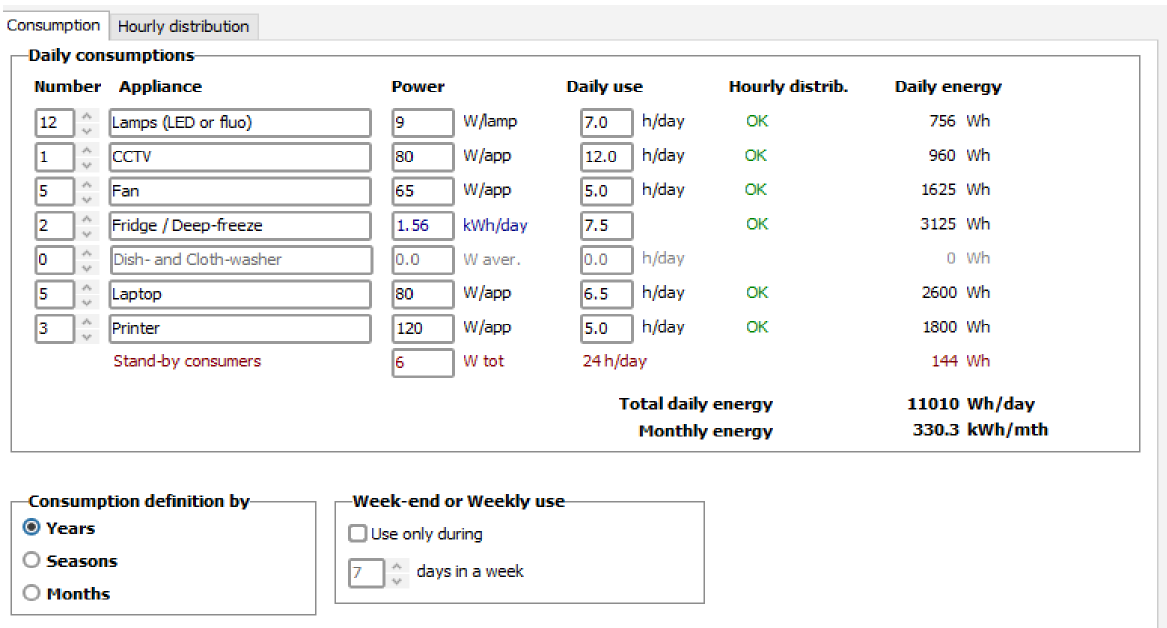

Figure 5. Loads Information on energy use

Step 4: PV system design and component sizing

Off-grid solar energy system is made to meet the daily needs of the Rest, and it needs to be able to recharge the battery bank sufficiently to provide power at night or when the sun is not shining. System size is the process of figuring out what voltage and current each part of the standalone PV system needs to operate in order to power the load. In figure 6 shown the PV system compounds.

PV Array Characteristics

PV module		**Battery**	
Manufacturer	LG Electronics	Manufacturer	Generic
Model	LG 300 N1C-A3	Model	Solar 12V / 160 Ah
(Original PVsyst database)		Technology	Lead-acid, sealed, Gel
Unit Nom. Power	300 Wp	Nb. of units	7 in parallel x 4 in series
Number of PV modules	10 units	Discharging min. SOC	20.0 %
Nominal (STC)	3000 Wp	Stored energy	43.0 kWh
Modules	5 Strings x 2 In series	**Battery Pack Characteristics**	
At operating cond. (50°C)		Voltage	48 V
Pmpp	2692 Wp	Nominal Capacity	1120 Ah (C10)
U mpp	57 V	Temperature	Fixed 20 °C
I mpp	47 A		

Controller		**Battery Management control**	
Universal controller		Threshold commands as	SOC calculation
Technology	MPPT converter	Charging	SOC = 0.90 / 0.75
Temp coeff.	-5.0 mV/°C/Elem.	approx.	52.8 / 50.1 V
Converter		Discharging	SOC = 0.20 / 0.45
Maxi and EURO efficiencies	97.0 / 95.0 %	approx.	47.2 / 48.9 V

Total PV power	
Nominal (STC)	3 kWp
Total	10 modules
Module area	16.4 m²
Cell area	14.3 m²

Figure 6. PV system design and component sizing

Step 5: setting of the seasonal tilt angle (summer and winter)

In this step, step 1, step 4 and step 4 is constant in this study, as shown in figure 7 seasonal tilt adjustment chosen from field type . after testing many seasonal tilt angle to find the optimum tilt angle for summer and winter. The PV Syst. suggested the seasonal summer and winter tilt angle are 20º, 50º respectively. the winter months chosen and the other months for summer as shown in figure 7.

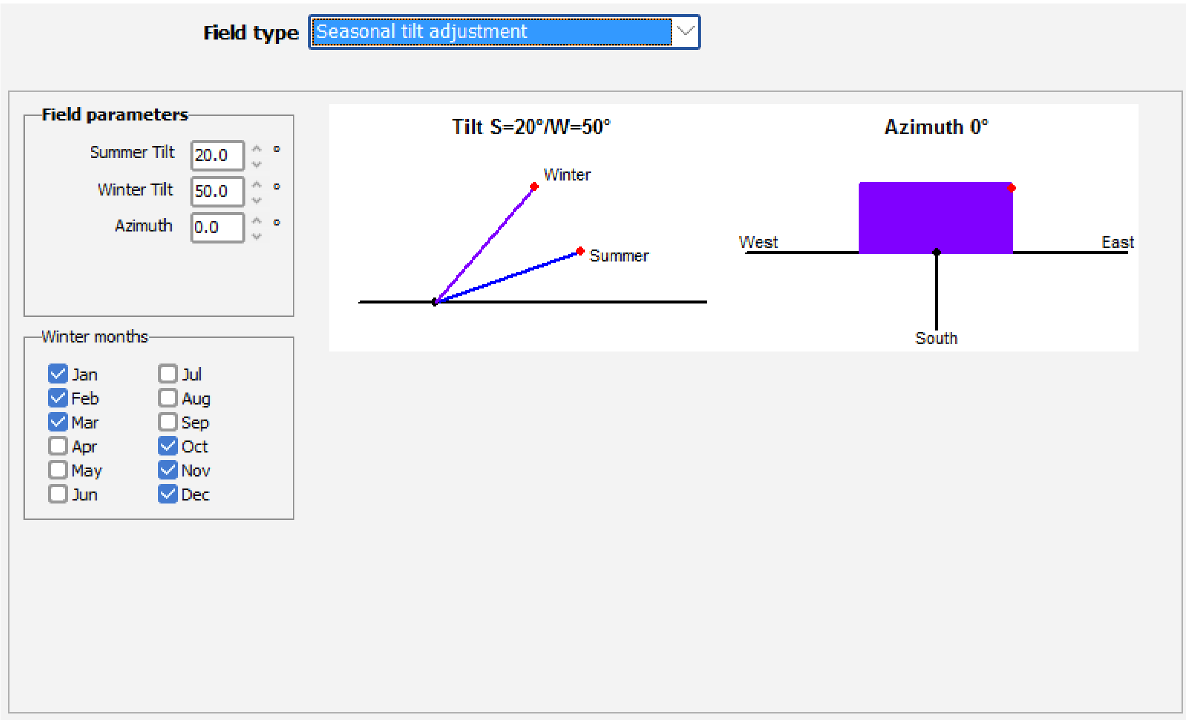

Figure 7. Seasonal tilt adjustment

Step 6: compute the results

The PVSyst software is used to compute the results for steps 2 and the results from step 5 the important results of this study calculate the maximum (TF), which means getting optimum tilt angle.

RESULTS

In this study, the Perez transposition model presently implemented in PSyst was chosen. Annual comparisons will be made between the outcomes of the cases according to the maximum system Production, maximum (TF), which signifies obtaining the optimum tilt angle.

Case 1: set the fixed tilted optimum tilt angle

From PV Syst. software suggest the 20º is the tilt angle the results shown in table 3.

Table 3. tilt angle suggest from PV syst. software

Angle Degree	System Production (Kwh/yr)	Normalized prod. (Kwh/kwp/day)	Performance ratio (%)	Array losses (Kwh/kwp/day)	TF (%)
20	4940	3,58	0,632	1,82	1,097

After testing, many tilt angle to obtain maximum (TF). The result shown in table 4.

Table 4. result for different tilt angle

Angle Degree	System Production (Kwh/yr)	Normalized prod. (Kwh/kwp/day)	Performance ratio (%)	Array losses (Kwh/kwp/day)	TF (%)
27	4987	3,63	0,636	1,81	1,106
28	4988	3,65	0,640	1,80	1,107
29	4988	3,65	0,639	1,80	1,107
30	4987	3,66	0,640	1,78	1,106
31	4986	3,66	0,642	1,78	1,106

As shown in table 4 the angles 28º and 29º have the same system Production (4988) Kwh/yr and same (TF) (1,107). The balances and main results of this two angle as shown in table 5.

Table 5. balances and main results of tilt angle 28º and 29º

Angle Degree	GlobHor (kWh/m²)	GlobEff (kWh/m²)	E_Avail (kWh)	EUnused (kWh)	E_Miss (kWh)	E_User (kWh)	E_Load (kWh)	Solar fraction (EUsed / ELoad)
28	1883,8	2031,3	4987,8	882,1	17,57	4000,9	4018,5	0,996
29	1883,8	2031,3	4988,2	883,5	24,33	3994,1	4018,5	0,994

Table 5 show the optical factors between these angles. Also in table 6 show the method of calculate the (TF) in PV syst software by applying equation (1) as follow.

$$TF = \frac{G_t}{G} = \frac{Global\ irradiation\ on\ tilted\ plane}{Global\ irradiation\ on\ horizontal\ plane} = \frac{GlobInc}{GlobHor} \qquad (3)$$

Table 6. Meteo and incident energy results of tilt angle 28º and 29º

Angle Degree	GlobHor (kWh/m²)	GlobInc (kWh/m²)	TF (%)
28	1883,8	2084,5	1,107
29	1883,8	2084,5	1,107

Based on the data presented in tables 2 and 3, it can be observed that for a tilt angle of 28 degrees, the performance ratio is higher compared to a tilt angle of 29 degrees. Additionally, the amount of missing energy is lower, while the solar fraction is higher as shown in figure 8.

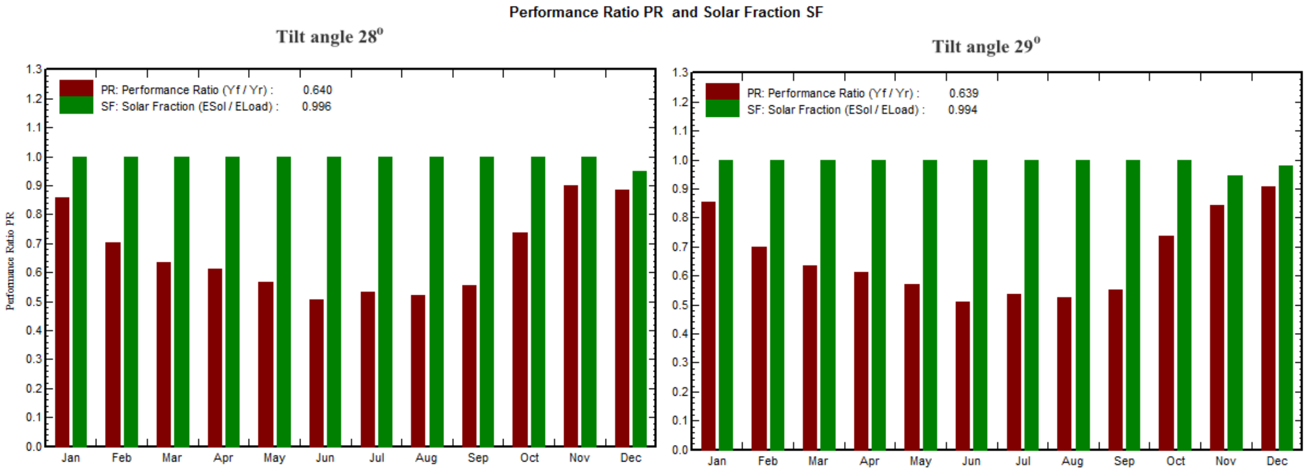

Figure 8. Performance ratio and solar fraction for tilt angle 28° and 29°

Case 2: set the seasonal tilt angle (summer and winter)

In this case From PV Syst. software suggest that the 20°, 50° are seasonal tilt angle for summer and winter respectively The System Production 5179 Kwh/yr., the Performance ratio is 0,620 and (TF) is 1,148 the results as shown in table 7.

Table 7. Results for seasonal tilt angle 20°, 50°

Angle S-W Degree	System Production (Kwh/yr)	Normalized prod. (Kwh/kwp/day)	Performance ratio (%)	Array losses (Kwh/kwp/day)	TF (%)
20-50	5179	3,67	0,620	1,97	1,148

After testing more than tilt angle for summer and winter season to obtain maximum system production with maximum (TF) the final result shown in table 8.

Table 8. The optimum seasonal tilt angle with maximum TF

Angle S-W Degree	System Production (Kwh/yr)	Normalized prod. (Kwh/kwp/day)	Performance ratio (%)	Array losses (Kwh/kwp/day)	TF (%)
12-50	5199	3,67	0,617	1,99	1,152

Table 9. Balances and main results for optimum seasonal tilt angle (12°, 50°)

Month	GlobHor (kWh/m²)	GlobEff (kWh/m²)	E_Avail (kWh)	EUnused (kWh)	E_Miss (kWh)	E_User (kWh)	E_Load (KWh)	SolFrac ratio
Jan.	91,8	144,3	383,6	17,2	0	341,3	341,3	1
Feb.	109,5	152,1	401,6	83,1	0	308,3	308,3	1
Mar.	150,7	173,3	443,8	100,1	0	341,3	341,3	1
Apr.	171,9	175,1	435,3	86,2	0	330,3	330,3	1
May	209,9	205,1	487	134,4	0	341,3	341,3	1
June	238,2	228,5	529,6	174,8	0	330,3	330,3	1
July	228,5	221,4	509,3	151,3	0	341,3	341,3	1
Aug.	214,5	215,8	496,9	143,9	0	341,3	341,3	1
Sep.	174,6	184,5	438,9	90,6	0	330,3	330,3	1
A)L.Oct.	124	154,6	380	44,6	0	341,3	341,3	1
Nov.	88,5	130,9	334,6	0	0	330,3	330,3	1
Dec.	81,8	134,9	358,3	20,5	0	341,3	341,3	1
Year	1883,8	2120,3	5199	1046,8	0	4018,5	4018,5	1

The monthly of the optical factors for optimum seasonal tilt angle (12°, 50°) as shown in table 10.

Table 10. the optimum seasonal tilt angle (12°, 50°)

Month	GlobHor (kWh/m²)	GlobInc (kWh/m²)	TF ratio
January	91,8	146,7	1,599
February	109,5	155	1,416
March	150,7	177,6	1,178
April	171,9	179,6	1,045
May	209,9	210,3	1,002
June	238,2	234,3	0,984
July	228,5	227	0,994
August	214,5	221,2	1,031
September	174,6	189,7	1,086
October	124	157,7	1,272
November	88,5	133,3	1,506
December	81,8	137,2	1,676
Year	1883,8	2169,5	1,152

As shown in table 10 the maximum monthly (TF) is in December, and minimum is in June and July which is related to temperature in PV module.

CONCLUSIONS

In the department of electrical engineering technologies at Al-Musayyib technical college in Iraq, this study examines and compares two possible positions for the installation of photovoltaic (PV) systems: a fixed titled plane and a seasonal tilt adjustment. In order to establish which of these options would result in the highest yearly transposition factor (TF) and the highest output system production power, this determination was carried out with the assistance of the PVSyst software. The conclusions that can be drawn from the research results are as follows:

- The transposition factors that were computed using PV Syst are consistent with equation (1). This is the case under the assumption that (GlobInc) is equivalent to (Gt), and (GlobHor) is equivalent to (G).
- The higher transposition factor for fixed orientation is 1,107 % at a tilt angle of (28°) , which is the optimal tilt angle at this site. The highest system production power is 498-kilowatt hours per year, the maximum energy delivered to the user is 4000,9-kilowatt hours per year, and the least amount of energy that is missing is 17,57-kilowatt hours per year.
- The higher transposition factor for seasonal orientation is 1,152 % at a tilt angle of (12°, 50°) for summer and winter, respectively, which is the seasonal optimal tilt angle at this site. The amount of energy that is delivered to the user is 4018,5-kilowatt hours per year, with the system production power being 5199-kilowatt hours per year. The amount of energy that is missing is 0,0-kilowatt hours per year, which means that the energy that is supplied to the user is equal to the energy that the user requires.
- To put it another way, the amount of solar radiation that is collected by the photovoltaic panel throughout the year can be optimized to acquire the greatest output power by making two annual adjustments to the tilt angle. This is in contrast to the practice of using a tilt angle that is set annually in order to reduce the cost of employing another orientation such as tracking.

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