Effect of Tilt Angle and Azimuth Angle on The Global Irradiance Using The PVsyst Software for Alkhums-Libya

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***Abstract*- In this paper aims to study the effect of the Tilt angle and Azimuth angle on Global irradiance of the Monocrystalline type PV module of off grid system for type fixed system in Alkhums city _ Libya using the PVsyst software. Where the study is carried out in two cases. The initial case is changed the value of the tilt angle from 0 degree to 90 degree in 10 step with freeze of azimuth angle on truth south and then at the second case it use the best value for the tilt angle as a fixed value and change the value of the azimuth angle from 310 degree to 40 degree in 10 step. To get the optimum tilt and azimuth angle for the month and year round of the year. The study showed the increase in solar radiation. Where the increase rate in the Global irradiance was 12.8%. The optimum tilt angle and azimuth angle for this study are 30^0 and 0.0^0 respectively. In order to validate the results, they were compared to other research (Solar-Med-Atlas, Photovoltaic Geographical Information System).**

Keywords- Alkhums city ,Tilt angle, azimuth angle, effective irradiance.

I. INTRODUCTION

Increasing worldwide demand for electricity coupled with growing concerns about climate change and the need to reduce the environmental impact of conventional fossil-fuel based power plants has led to the development of innovative and more sustainable power generation solutions based on renewable resources. [1]. One of the most promising sources for the generation of clean energy is solar energy because of its salient features like it supports distributed generation, needs minimum maintenance, payback period is small etc. There are two main types of solar energy technologies that can harvest this abundant energy resource; solar photovoltaic (PV) and concentrating solar power (CSP).[2] Photovoltaic systems (PV) converts the sun heat energy directly into electrical energy while concentrated solar power (CSP) systems first convert the solar energy into thermal energy and then further convert it into electrical energy through a typical thermal engine.[2]

Libya is one of the developing countries in which photovoltaic system was first put into work in 1976 to supply electricity for a cathodic protection station. Since then; the use of photovoltaic systems is widely used in size and applications as standalone systems.[3]

The tilt angle and azimuth angle play important role towards the efficiency of the plant. Thus, it is very important to orient the solar panels at tilt angle and azimuth angle for any given location.

The default value is a tilt angle equal to the station's latitude plus 15 degrees in winter, or minus 15 degrees in summer [4]. This normally maximizes annual energy production**.** The tilt angle of PV panel is given in fig. 1.

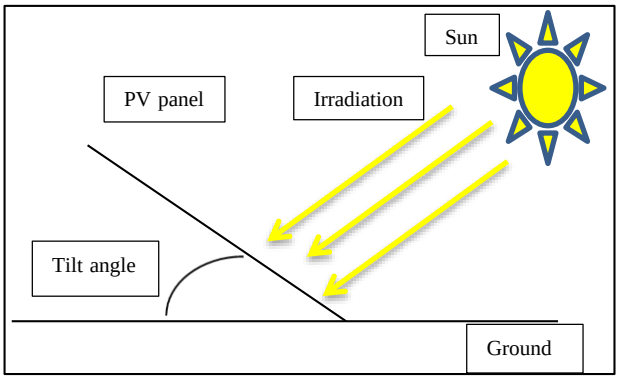

Figure 1. Tilt angle of PV panel.

Solar azimuth angle is the azimuth angle of the sun; it defines the direction the sun is in [4].The most commonly accepted convention for analyzing solar irradiation, e.g. for solar energy applications, is clockwise from due South, thus West is 90° , North is 180.0° and East is 270° which is shown in Fig .2.[5]

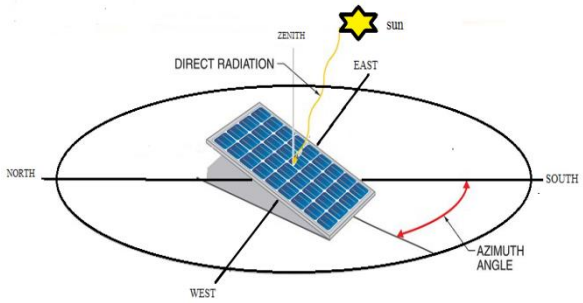

Figure 2.Azimuth angle of solar panel/array

II. PV_{SYS} SOFTWARE

PVsyst V6.84 is a PC software package for the study, sizing and data analysis of complete PV systems. It deals with grid-connected, stand-alone**,** pumping and DC-grid (public transportation) PV systems, and includes extensive meteo and PV systems components databases, as well as general solar energy tools.[6]

The process of designing an off grid system in PVsyst includes the following basic steps:

1. Project – define the location and meteorological data
2. Orientation – define module azimuth and tilt
3. System – choose the system modules and electrical design
4. Detailed Losses – Near Shading loss is set to 0% for an off grid system (open space)
5. Simulation – view a summary of the system's energy output

III. METHODOLOGY

The methodology to find out optimum tilt angle and azimuth angle is given in tow steps:

A: Methodology for Effect of tilt angle on the Global irradiance and find out optimum tilt angle

1. Chose PV module, keep it to true south
2. very tilt angle starting from 0.0 degrees to 90 degrees in steps of 10 degrees
3. Set IAM (Incidence Angle Modifier) loss = 0.
4. Tabulate the results of each tilt angle (Effective global monthly as well as annually)
5. Compare the results and find out optimum tilt angle monthly as well as annually.

B: Methodology for Effect of Azimuth angle on the Global irradiance and find out optimum azimuth angle

1. Chose PV module
2. Set module to optimum tilt angle
3. Start varying azimuth from 310 degrees to 40 degrees (0.00 is true South) in steps of 10 degrees
4. Tabulate the results of each azimuth angle (Effective global monthly as well as annually)
5. Compare the results and find out optimum azimuth angle Effective global irradiance (monthly as well as annually).

IV. SIMULATION RESULT AND DISCUSSES

Al khums's longitude is 14.2639 degrees and latitude is 32.6504 degrees**.** The project name and its address are provided then the software automatically takes up the longitude and latitude. In the present study, the meteorological data is acquired from Meteonorm version 7.2, a comprehensive climatological database for solar energy applications**.**

Fig. 3, illustrates the sun path diagram for the location of Alkhums city. This shape expresses the apparent path of the sun facing the system, where it shows the outer path is the maximum path of the sun reaches in the summer and the inner path expresses the winter path of the sun and between them falls with the rest of the year. The organization is installed in an open space. The tilt angle of the PV array is the key to achieving the best orientation of the solar panel toward solar radiation. The energy usage between winter time and summer time is big, otherwise at this latitude the solar resource gap between winter and summer not that big .that is the reason why the inclination needs to be optimized for the summer months.

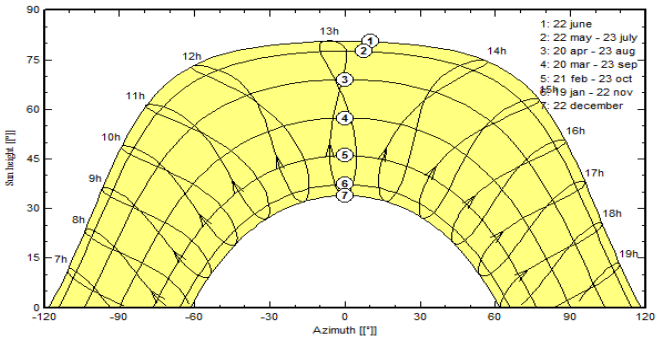

Figure 3. Sun path diagram for the location of Alkhums city_Libya [PVsys software, Meteonorm 7.2]

PV module used for the analysis is Solarworld_Sunmodule_XL_SW_340_mono.PAN

Table I. shows the horizontal Global irradiance of Al khums city (monthly and year). Global Irradiance is the amount of energy reaching the earth on a horizontal surface (tilt angle = 0, azimuth angle = 0).

Table I. Horizontal global irradiance of Al khums city [PVsys software, Meteonorm 7.2]

Month	**Horizontal global Irradiance kWh/m².mth**
January	100.9
February	116.7
March	168.1
April	199
May	230.5
June	234.3
July	245.8
august	221.8
September	177
October	141
November	109.2
December	90.4
Year	2034.6

- *Case 1: Study of effect of tilt angle on Global incident in collection plane:*

In the analysis, the tilt angle is varied from 0 degrees to 90 degrees in steps of 10 degrees. At different tilt angles, the Effective Global irradiance is noted down and the effect of tilt angle is compared.

The design is created by selecting the area in which off grid PV plant is to be installed. Then following inputs are provided:

Set the location longitude is 14.2639 degrees and latitude is 32.6504 degrees.

1. Azimuth angle =0 degrees.
2. Tilt angle = varied in between 0 degrees to 90 degrees in step of 10 degrees.

3. PV module of 340 Watt
4. String length = 1,

Then the weather condition set is provided and then design is simulated. The Monthly and Annual Effective Global irradiance at various tilt angles in each month (kWh/m^2) of the year as well as annual is given in Table II.It can be observed that the annual effective radiation value increase as the tilt angle value approaches 30^0 and then begins to decrease whenever it exceeds this value, indicating that the highest effecting annual effective irradiation value can be obtained when the tilt angle value is 30^0.

Table II.Monthly and Annual Effective Global irradiance Various Tilt Angles

Tilt angle	**0.0^0**	**10^0**	**20^0**	**30^0**	**40^0**	**50^0**	**60^0**	**70^0**	**80^0**	**90^0**
Jan kWh/m^2	100.8	121.7	139.5	153.8	163.9	169.7	171	167.7	159.9	147.9
Feb kWh/m^2	116.6	134.4	148.7	159.2	165.6	167.7	165.4	158.8	148	133.5
Mar kWh/m^2	168.1	183.8	194.9	201.0	202.0	197.8	188.6	174.6	156.3	134.2
April kWh/m^2	198.8	207.8	211.5	209.8	202.8	190.7	173.9	153.1	128.8	101.9
May kWh/m^2	230.5	232.7	229	219.5	204.5	184.5	161	134.3	104.3	74.1
June kWh/m^2	234.3	231.9	224.4	211.6	193.5	170.9	145.9	117.8	87.8	57.6
July kWh/m^2	245.8	245.3	238.7	226.4	208.4	185.7	159.3	129.9	97.7	65.5
Aug kWh/m^2	221.7	228.4	229.3	224.2	213.4	197.2	176.3	151.5	123.5	92.8
Sept kWh/m^2	176.9	190	198.3	201.5	199.6	192.5	180.7	164.3	143.8	120.1
Oct kWh/m^2	140.9	158.8	172.7	182.3	187.1	187.2	182.4	172.9	159.1	141.3
Nov kWh/m^2	109.1	130.8	149.1	163.6	173.7	179.1	179.8	175.6	166.7	153.3
Dec kWh/m^2	90.4	110.5	127.8	141.9	152.2	158.5	160.6	158.4	152	141.5
Year kWh/m^2	2034	2176.1	2263.8	**2294.7**	2266.7	2181.5	2045	1858.9	1627.9	1363.7

- *Case 2: Study of effect of azimuth angle on solar PV output*

All the inputs in design are same as before in study of tilt angle only the azimuth angle is varied between 310 degrees to 40 degrees where 0.0 degree is true south. The tilt angle is now freezing to 30 degrees which is optimum tile angle for Al khums according to Effective Global irradiance generated. Then following inputs are provided:

1. Set the location longitude is 14.2639 degrees and latitude is 32.6504 degrees.
2. Tilt angle = 30 degrees
3. Azimuth angle = varied in between 310 degrees to 40 degrees in step of 10 degrees
4. PV module of 340 Watt
5. String length = 1,

The weather condition set is provided for Al khums and the design is simulated. The Effective Global irradiance monthly and annually in kWh/m^2 for various azimuth angles is respectively given in Table III.The value of Effective Global irradiance in the summer is greater than the value of Effective Global irradiance in the rest of the year due to the availability of the sun for a longer time. The highest effecting global irradiation value can be obtained when the azimuth angle value is 0.0^0. Given that the apparent solar path is not completely circular, the solar panel must be shifted from the south to specific angles which is explained by the value of effective solar irradiation in Table III corresponding to the non-zero azimuth angle

Table III.Monthly and Annual Effective Global irradiance various azimuth Angles

Azimuth Angle	**310^0**	**320^0**	**330^0**	**340^0**	**350^0**	**0.0^0**	**10^0**	**20^0**	**30^0**	**40^0**
Jan kWh/m^2	130	137.5	144.1	149.1	152.3	153.8	153.3	151	146.8	141
Feb kWh/m^2	141.3	147.6	152.7	156.4	158.6	159.2	158.2	155.7	151.7	146.7
Mar kWh/m^2	182.3	188.2	192.9	196.4	199.4	201.0	201.2	199.9	197.1	193.2
Apr kWh/m^2	200	203.4	205.8	207.3	208.8	209.8	209.9	209.8	209	207.3
May kWh/m^2	218.1	218.9	219.2	219.1	219.2	219.5	219.5	219.8	220	219
Jun kWh/m^2	216.4	217	215.2	212.9	212.0	211.6	211.0	212	213.5	212.7
July kWh/m^2	226.6	227.4	226.9	226.1	226.3	226.4	226.4	228.2	229.7	229
Aug kWh/m^2	220.4	222.2	223.3	223.5	224.2	224.2	223.5	223.2	222.2	220.5
Sept kWh/m^2	190.6	194.6	197.9	200	201.2	201.5	200.5	198.8	196.5	193
Oct kWh/m^2	161.1	167.2	172.9	177.5	180.7	182.3	182.2	180.5	177.3	172.6
Nov kWh/m^2	142.1	149.4	155.5	160	162.8	163.6	162.5	159.4	154.6	148.1
Dec kWh/m^2	120.2	127.5	133.6	138.1	140.9	141.9	141.1	138.5	134.3	128.5
Year kWh/m^2	2149.4	2200.9	2239.9	2266.6	2286.3	**2294.7**	2289.4	2276.8	2252.8	2211.6

From Tables II and III, the optimum tilt angle and azimuth angle value differ from month to month and therefore for a non-fixed system the solar panel can be directed according to the best value for each month .Table IV, shows the optimum tilt angle and azimuth angle for a non-fixed system, The optimum tilt angle and azimuth angle for fixed system are 30^0 and 0.0^0 respectively.

Table IV. Month-wise Tilt and azimuth Angle

Month	Tilt angle	Azimuth Angle
January	60^0	0.0^0
February	50^0	0.0^0
March	40^0	10^0
April	20^0	10^0
May	10^0	30^0
June	0.0^0	320^0
July	0.0^0	30^0
august	20^0	0.0^0
September	30^0	0.0^0
October	50^0	0.0^0
November	60^0	0.0^0
December	60^0	0.0^0

The correct orientation of the solar panel in the direction of the solar radiation would increase the value of the output energy of the system. Fig. 4, shows the Effective Global irradiance, which increased its value by to the direct orientation towards the solar irradiation, where it's increased by 12.8%.

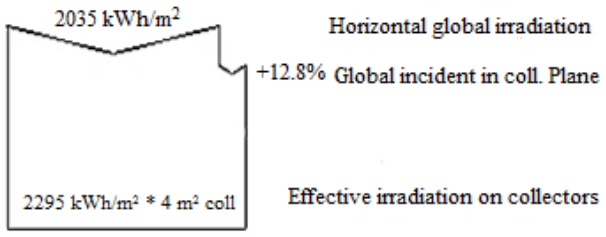

Figure 4. Effective Global irradiance

Table VI and Fig. 5, are shown a comparison of the horizontal global irradiation of Al khums city (monthly and year). obtained from PVsys software, Solar-Med-Atlas[7] and Photovoltaic Geographical Information System (PVGIS)[8] PVsys software results are within the engineering error permissible.

Table VI. The horizontal global irradiation of Al khums city (monthly and year). obtained from PVsys software, Solar-Med-Atlas and Photovoltaic Geographical Information System (PVGIS)

Month	Horizontal global Irradiance kWh/m².mth		
	PVsys	PVGIS	Solar Med Atlas
January	100.9	102.39	98
February	116.7	116.05	118
March	168.1	166.32	165
April	199	200.68	195
May	230.5	210.18	221
June	234.3	221.05	232
July	245.8	244.41	240
august	221.8	220.35	216
September	177	170.18	172
October	141	134.38	138
November	109.2	93.97	104
December	90.4	73.89	86
Year	2034.6	1953.85	1983

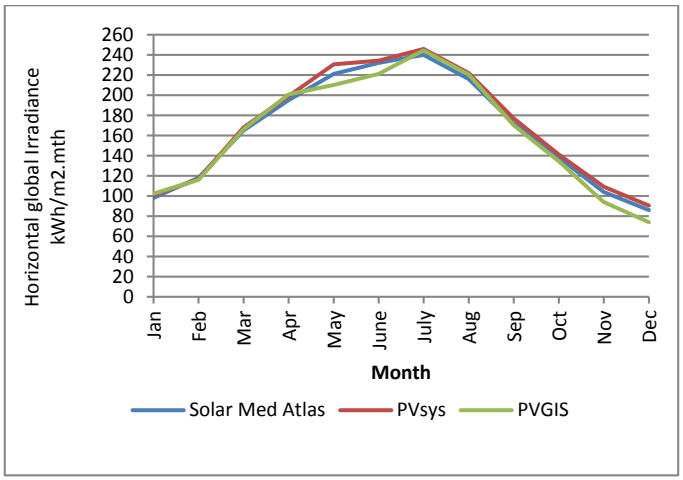

Figure 5. The horizontal global irradiation of Al khums city (monthly and year). Obtained from PVsys software, Solar-Med-Atlas and Photovoltaic Geographical Information System (PVGIS).

V. CONCLUSION

In this study, solar radiation in Alkhoms city was simulated and her relationship to changing the Tilt angle and Azimuth angle of inclination and in an open space area and during conditions (IAM loss = 0, shading = 0). It is noted that if there is fixed system then the optimum tilt angle is 30degree and the azimuth angle is 0 degree for Al khums, while for a non-fixed system, the tilt angle and azimuth angle change from month to month. The slop of the solar panels is changed in order to obtain full compatibility with the fallen solar radiation. The study showed the increase in the produced energy due to the increase the solar radiation. Where the increase rate in the Global irradiance was 12.8%.

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