ENGINEERING RESEARCH JOURNAL (ERJ)

Vol. 1, No. 39 Jan. 2019, pp.46-55.

Journal Homepage: www.feng.bu.edu.eg

Experimental and Simulation of Solar Radiation Absorbed by Inclined Photovoltaic with Low Concentration

Prof.Dr. Osama Ezzat Abdellatif[1], Dr. Aref Eliwa[2], Dr. Mohamed Aly Ibrahim[3], Eng. Ahmed Hamdi Abdel-Wahed[4]

[1] Benha University, Shoubra Faculty Of Engineering, Mechanical Engineering, Cairo, Egypt.

[2] Electronics Research Institute, Eldokki, Giza, Egypt.

[3] October 6 University, Faculty Of Engineering, 6th of October City, Giza, Egypt

[4] October 6 University, Faculty Of Engineering, Mechatronics Engineering, 6th of October City, Giza, Egypt

ABSTRACT. One of the essential factors which must be considered in the design and employment of photovoltaic system is the Solar radiation. The effectiveness of the PV system is improved and at the same time the expense of electricity generation is decreased by using concentration photovoltaic. A V-trough integrated with low concentration PV system was utilized (LCPV) to get this aim. To improve the amount of absorbed radiation, optical modelling Of V-trough was performed. Mathematical model for estimation of solar radiation is showed in this research. The beginning point is demonstrated by the mathematical model of extraterrestrial radiation, producing eventually in the model for solar radiation, absorbed by a low concentration photovoltaic panel. Positions of reflectors has been modified and optimal position of reflectors has been determined by both experimental measures and numerical calculations to get superior concentration of solar radiation intensity. The calculated values have been discovered to be in good coincidence with the measured ones, both leading to the optimal position of the flat reflector to be α_1 = 35° (angle of lower reflector with horizontal) and α_2= 5 ~ 15° (angle of upper reflector with vertical). These assessment models for solar radiation have been specialized located in the 6th October city, Egypt, and have been proved by numerical simulation. In this research, a comparative analysis was also performed with respect to the solar irradiation absorbed by the PV panels with solar radiation and without concentration absorbed by a low concentration photovoltaic panel. This analysis was depending on the output of numerical simulation and experimental trials.

Keywords : Low concentrating photovoltaic system (LCPV), Photovoltaic panel (PV), hourly solar radiation.

1. INTRODUCTION

The combustion of fossil fuels and pollutants and greenhouse emissions is concerned with the worry over their depletion which could be tackled by mainly two ways: 1) substitute fossil fuel by renewable energy source. 2) practice energy efficiency in all aspects of energy consumption, production, distribution to get the same useful result while consuming minimum amount of fuel. Renewable energy can directly substitute fossil fuels while energy efficiency can only decrease consuming fuel. Major renewable energy sources include solar, geothermal, wind, biomass, hydropower. Wave, ocean, tidal energies are also renewable sources, but presently they are costly, and technologies are yet in the experimental stage [1]. The most plentiful energy source on the earth is the sun. All fossil fuel, wind, biomass, hydro energies have their origin in sunlight. The rate of falling solar energy on the surface of earth is 120 megawatts, (1 pet watt = 1015 watt), which means that all delivered solar energy from sun for one day could satisfy the whole world need for more than 20 years. Many photovoltaic stations have been established, because of the great solar potential over Africa region. But it's recorded that these solar plants occupy a large area of agricultural land. This research is the beginning study which targets to address significantly the matters of raising the effectiveness of photovoltaic systems with the employment of solar radiation concentrator elements and decreasing of expensive photovoltaic surface. Analysis of a system converting solar energy to electric energy is depending on an exact estimation of solar radiation in the site. The average of daily solar radiation absorbed by the PV panels every hour without concentration and those with self-control of the solar radiation is estimated by a computer model which was promoted for that and compare the analysis with experimental tests.

2. MATHEMATICAL MODELLING AND SIMULATION OF SOLAR RADIATION

We can begin from the mathematical model of extraterrestrial radiation for obtaining the mathematical model of solar radiation absorbed by a photovoltaic panel provided with a low radiation concentration system.

2.1 The Theoretical of Extraterrestrial Radiation.

The dependence of extraterrestrial radiation incident on the plane normal to the radiation on the *n*th day of the year is shown in Fig 1. A simple equation with accuracy adequate for most engineering calculations is given by [1];

$$G_{0n} = G_{sc}(1 + 0.033cos\frac{360\,n}{365}) \quad 1$$

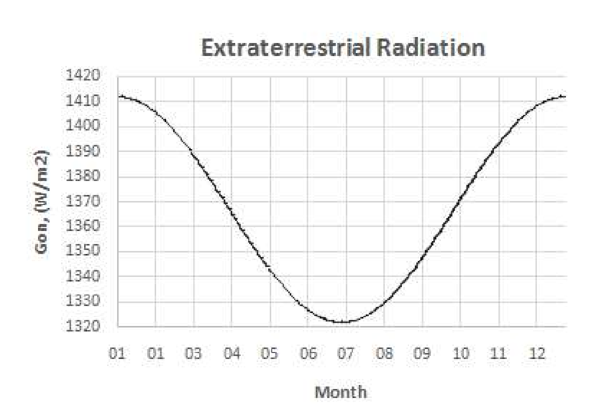

Fig 1 Variation of extraterrestrial solar radiation with nth day of year.

At any point in time, the solar radiation incident on a horizontal plane outside of the atmosphere is the normal incident solar radiation as given

$$G_0 = G_{0n}\, cos\theta_z \quad 2$$

$$G_0 = G_{sc}\left(1 + 0.033cos\frac{360\,n}{365}\right)cos\theta_z \quad 3$$

Equation relating the angle of incidence of beam radiation on a surface, θ, to the other angles is;

$$\cos\theta = \sin\delta\sin\phi\cos\beta - \sin\delta\cos\phi\sin\beta\cos\gamma + \cos\delta\cos\phi\cos\beta\cos\omega + \cos\delta\sin\phi\sin\beta\cos\gamma\cos\omega + \cos\delta\sin\beta\sin\gamma\sin\omega \quad ....4$$

If Eq. (**Error! Reference source not found.**) apply on horizontal surface zero inclination angle,($\beta = 0$) as shown in *Fig 2* the incidence angle (θ) become solar zenith angle (θ_z), and solar altitude angle (α_s) calculated from;

$$cos\theta_z = sin\,\alpha_s = sin\,\delta\,sin\,\phi + cos\,\delta\,cos\,\phi cos\,\omega \quad ......5$$

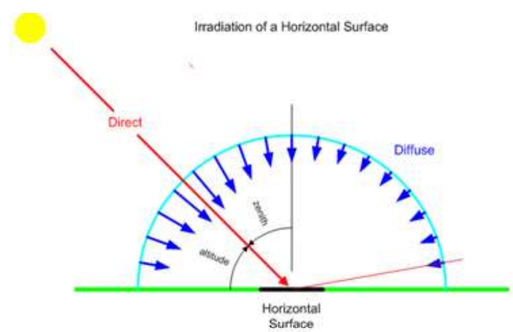

Fig 2 Direct solar beam on horizontal surface

The optimum azimuth angle for PV panels is usually 0°in the northern hemisphere (or 180°in the southern hemisphere). Thus, it is a common situation that $\gamma = 0°$ (or 180°).

$$\cos\theta = \sin\delta\sin\phi\cos\beta - \sin\delta\cos\phi\sin\beta + \cos\delta\cos\phi\cos\beta\cos\omega + \cos\delta\sin\phi\sin\beta\cos\omega \quad ....6$$

$$\cos\theta = \sin\delta\sin(\phi - \beta) + \cos\delta\cos(\phi - \beta)\cos\omega \quad .....7$$

Declination angle (δ) can be calculated as a function of the day number *n*.

$$\delta = 23.45sin\left[360°\frac{284 + n}{365}\right] \quad 4$$

The value of *n* for *i*th Day of Month taken from Table **1** for calculating declination angle (δ).

Table 1 Recommended average day for months

Month	Day Number	Month	Day Number
January	i	July	181+i
February	31+i	August	212+i
March	59+i	September	243+i
April	90+i	October	273+i
May	120+i	November	304+i
June	151+i	December	334+i

The solar hour angle (ω) is the displacement of the sun east or west of the local meridian due to rotation of the earth on its axis at 15°per hour; morning negative, afternoon positive.

$$\omega = 15\,(\text{solar time} - 12) \qquad (\text{degree}) \quad 5$$

For calculating the solar time, you need to know the local (clock) time, If it's daylight saving time, the local longitude. As the sun takes 4 minutes to transverse 1 of longitude. The correction is subtracted from the clock time whether the site is east of the standard meridian and it's added whether the site is east. The general equation used to calculate the obvious solar time is

$$SolarTime = StandardTime \pm 4(L_{st} - L_{loc}) + E - DS \quad (min) \qquad 10$$

The equation of time (E) in minutes as a function of time of year

$$E = 229.2(0.000075 + 0.001868 cosB - 0.032077 sinB - 0.014615 cos2B - 0.04089 sin2B) \qquad 11$$

$$B = (n-1)\frac{360}{365} \qquad 12$$

Several angels are marked in figure 3 represents the geometrical relations between a plane of any specific orientation relative to the earth at any time and the incoming beam solar radiation of the sun relative to that plane.

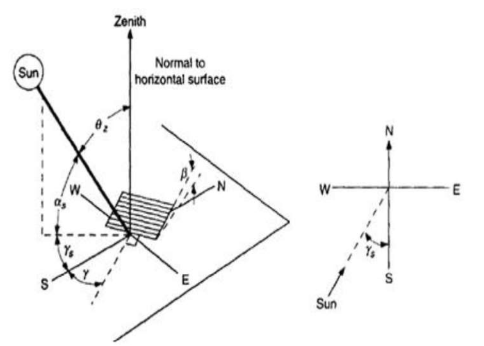

Fig 3 (a) Angles of solar beam and tilted surface. (b) Plan view of solar azimuth angle

The solar azimuth angle (γ_s) is from

$$\gamma_s = \text{sign}(\omega)\left|cos^{-1}\left(\frac{\cos\theta z \sin\phi - \sin\delta}{\sin\theta z \cos\phi}\right) \qquad 13\right|$$

The sign function in Eq. (**Error! Reference source not found.**)make the sign of γ_s and ω the same, before noon are ***negative*** and after noon are ***positive***.

2.2 Ratio of beam radiation on tilted surface to that horizontal surface

Proportion of beam radiation on inclined surface to that on horizontal surface:

The geometrical factor R_b, by suitable use of Equation 15 , the proportion of beam radiation on the inclined surface to that on the horizontal surface at any time could be calculated.

$$R_b = \frac{G_{bt}}{G_b} = \frac{G_{bn}\, cos\theta}{G_{bn}\, cos\theta_z} = \frac{cos\theta}{cos\theta_z} \qquad 14$$

$$R_b = \frac{\sin\delta\sin(\phi-\beta) + \cos\delta\cos(\phi-\beta)\cos\omega}{\sin\delta\sin\phi + \cos\delta\cos\phi\cos\omega} \qquad 15$$

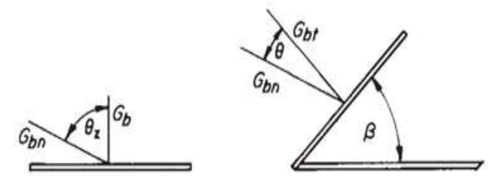

Fig 4 Beam radiation on horizontal and tilted surfaces.

2.3 Hourly and Daily Extraterrestrial Radiation.

The hourly extraterrestrial radiation strikes on a horizontal surface can be estimated from Eqn. (3) by integrating it between hour angles ω_1 and ω_1. The integration for an hour period results in the following equation, where $I_o$is the hourly extraterrestrial radiation on horizontal surface, J/m^2 hr.

$$I_0 = \frac{12\times3600}{\pi}G_{0n}\left[cos\delta\, cos\phi \sin(\omega_2-\omega_1) + \frac{\pi(\omega_2-\omega_1)}{180}\sin\delta\, sin\phi\right] \qquad 16$$

The hourly extraterrestrial radiation can also be determined from the following approximate equation, evaluating at the mid-point of the hour.

$$I_0 = 3600 \times G_{0n}(\cos\delta\cos\phi\cos\omega + \sin\delta\sin\phi) \qquad 6$$

For calculation of daily solar radiation to have the integrated daily extraterrestrial radiation on a horizontal surface, H_o. This is obtained by integrating Eq. (6) over the period from sunrise to sunset. $H_o$is the daily extraterrestrial radiation on horizontal surface, J/m^2 day.

$$H_o = \frac{24\times3600}{\pi}\times G_{0n}(cos\delta cos\phi sin\omega_s + \frac{\pi\omega_s}{180}\sin\delta sin\phi) \qquad 7$$

where $\omega_s$is the sunset hour angle, in degrees, from

$$\cos\omega_s = -\frac{\sin\phi\sin\delta}{\cos\phi\cos\delta} = -\tan\phi\tan\delta \qquad 8$$

The sunrise hour angle is the negative of the sunset hour angle. It also follows that the number of daylight hours is given by

$$N = \frac{2}{15}cos^{-1}(-\tan\phi\tan\delta) \qquad 9$$

2.4 Estimation of Average Solar Radiation on a Horizontal Surface

At a particular location, the main Angstrom-type recession equation relates monthly average daily radiation to radiation in a clear day. The average fraction of probable sunrise hours is calculated by

$$\frac{H}{H_o} = a + b\frac{\bar{n}}{\bar{N}} \quad 10$$

Values of $H_o$can be calculated from Eqn. (7), the average day length *N* can be calculated from Eqn. (10) and constants *a* and *b* for various climate types and locations based on radiation data then available.

2.5 Estimation of Hourly Solar Radiation on a Horizontal Surface from Daily Data

It's important to begin with daily data then measure hourly values from daily data, when hour-by-hour performance assessment for a solar system are required. The proportions of hourly overall radiation I to daily total radiation *H* on a horizontal surface is represented as a function of day length. The proportion *I/H* is represented by the next equation.

$$\frac{I}{H} = \frac{\pi}{24}(C_1 + C_2 \cos\omega)\frac{co\,s\,\omega - co\,s\,\omega_s}{\sin\omega_s - \frac{\pi\omega_s}{180}co\,s\,\omega_s} \quad 11$$

where the parameters $c_1$and $c_2$are given by:

$$C_1 = 0.409 + 0.5016\sin(\omega_s - 60) \quad 12$$

$$C_2 = 0.6609 - 0.4767\sin(\omega_s - 60) \quad 13$$

2.6 Beam and Diffuse Components of Hourly Global Radiation on a Horizontal Surface.

An hourly clearness index (k_{hr}) can be defined as

$$K_{hr} = \frac{I}{I_o} \quad 14$$

where *I* is the hourly global radiation on a horizontal surface, J/m^{2}hr. The usual approach is to correlate I_d / *I*, which expresses the fraction of the hourly radiation on a horizontal plane which is diffuse, with k_{hr}, the hourly clearness index. $I_d$is the hourly diffuse component of global radiation (*I*). This correlation may not represent a particular hour very closely, but over a number of hour it adequately represents the diffuse fraction. The three correlations are essentially identical, although they were derived from three separate data sources. The correlation between hourly d iffuse and global radiation developed by (Erbs et al. [2]) is as follows:

$$\frac{I_d}{I} = 1 - 0.09K_{hr} \qquad K_{hr} \le 0.22 \quad 15\text{-a}$$

$$\frac{I_d}{I} = 0.9511 - 0.1604K_{hr} + 4.338K_{hr}^2 - 16.638K_{hr}^3 + 12.336K_{hr}^4 \qquad 0.22 < K_{hr} \le 0.8 \quad 16\text{-b}$$

$$\frac{I_d}{I} = 0.165 \qquad K_{hr} > 0.8 \quad 17\text{-c}$$

2.7Hourly Radiation on a Tilted Surface

The radiation on the tilted surface include three components: beam, isotropic diffuse, and solar radiation diffusely reflected from the ground as shown in *Figure 5*. A surface tilted at slope *β* from the horizontal has a view factor to the sky F_{c-s}. The tilted surface has a view factor to the ground F_{c-g}, and if the surroundings have a diffuse reflectance of ρ_g. The total solar radiation on the tilted surface for an hour as the sum of three terms [2]:

$$I_T = I_b R_b + I_d F_{c-s} + I\rho_g F_{c-g} \quad 18$$

$$I_T = I_b R_b + I_d\left(\frac{1+\cos\beta}{2}\right) + I\rho_g\left(\frac{1-\cos\beta}{2}\right) \quad 19$$

where $I_T$is total hourly radiation incident on a tilted surface and *β* is the slope of the surface considered in degrees. Values of $R_b$can be calculated from Eqn. (**Error! Reference source not found.**).

Table 2 Reflectivity ρ_g Values

Ground Cover	Reflectivity	Ground Cover	Reflectivity
Dry bare ground	0.2	Pale soil	0.3
Dry grassland	0.3	Dark soil	0.1
Desert sand	0.4	Water	0.1
Snow	0.5-0.8	Vegetation	0.2

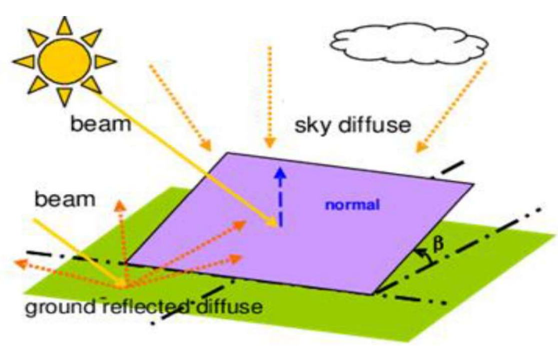

Figure 5Solar radiation on tilted surface

3 SIMULATION OF HOURLY RADIATION

A computer model was developed to simulate the hourly average of daily solar radiation on horizontal and inclined surfaces. The measured hourly solar radiation was compared with simulated radiation, and favorable agreement was observed for the measured and predicted values on clear days. According the parameter of the radiation on the tilted surface as shown in *Figure 5* and the equation of the solar radiation on the tilted surface for an hour as the sum of three terms can be calculated from Eqns(29-30)

Using Microsoft EXCEL to make a mathematical model that can be depend on the location of PV module, direction and tilted angle from these parameters can be estimate the hourly average of daily solar radiation. Experimental results have a good agreement with data generated from mathematical model. Using two user graphic interface to insert parameters and generate data of output parameter with graph.

Input Data		Output Data	
Standard Longtidude(degree) =	30	Solar Time =	11:29 AM
Local Longtidude(degree) =	31	Declination angle δ =	13.72
Local Latitude ϕ (degree)=	30	Hour angle ω =	-7.72
Location from Greenwich =	East	Angle of Incidence θ =	15.70
Standard Time (hr : mm) =	11:30 AM	Zienth angle θz =	17.77
Day =	15	Solar azimuth angle ϒs =	-25.3
Month =	August	Solar altitude angle αs =	72.23
Tilted angle β (degree)=	30	Total incident solar radiation (W/m2) =	1070
surface azimuth angle ϒ =	0	Solar Altitude A (m) =	73.7
Type of reflected ground	Desert sand	Number of Daylight hours =	13.1
Half Apex Angle for Flat Concentrator α		Maximume Concentration (C) =	1.2
Clouded Day (Y/N)	No	Maximume Radiation on the day =	1083
Angle for Lower Flat Concentrator α1	35		
Angle for Upper Flat Concentrator α2	5		

Figure 6Input and output parameters from EXCEL model.

As shown using all parameters that can affect in hourly average of daily solar radiation such as location (local longitude, local latitude), month, tilted angle of PV module, direction (surface azimuth angle), type of reflected ground and state of clouded day (Y/N), from all input parameters and the data analysis by EXCEL generate the prediction of data of hourly average of daily solar radiation and validate the data with experimental results. Example As shown in the *Figure 6*, the parameters for the month of August were used with the results of the angles of concentration and influence on the solar radiation

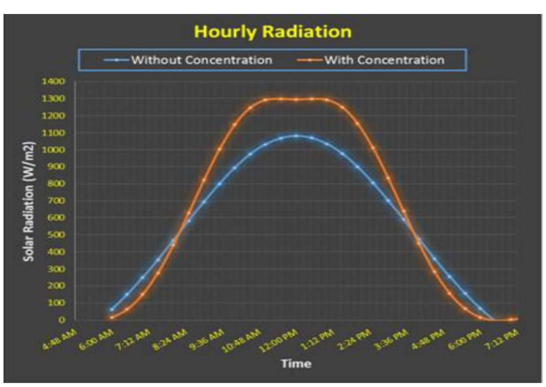

Figure 7 Hourly solar radiation and concentration in August.

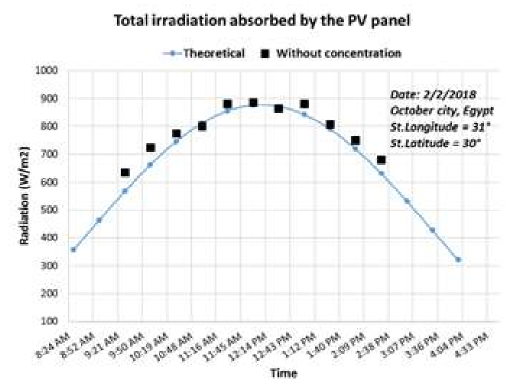

Figure 8 Comparison experimental irradiation absorbed by the PV panel with theoretical results in 22 February.

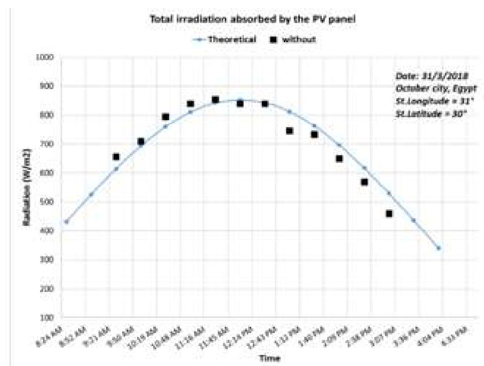

Figure 9 Comparison experimental irradiation absorbed by the PV panel with theoretical results in 31 March.

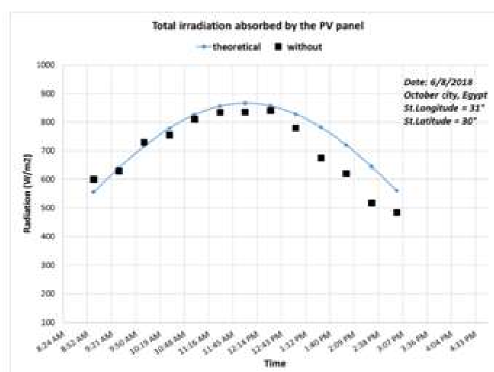

Figure 10 Comparison experimental irradiation absorbed by the PV panel with theoretical results in 6 August.

4 CONCENTRATOR PHOTOVOLTAICS (CPV)

Concentrator Photovoltaic (CPV) is one of the technologies that has attracted a renewed interest due to the increased search for the use of non-fossil fuel-based sources of energy to mitigate environmentally damaging effects of using fossil fuel for electricity production. The main concept of CPV is to make use of optical systems to increase the density of irradiance incident upon the solar cells. Operating solar cells under concentrated illumination offers two main advantages. The first is that fewer solar cells are required due to incorporation of an optical system to concentrate incident irradiance from the sun onto reduced area of conventional solar cells. The second advantage is that this increase in the density of irradiance incident upon the solar cells increases the electrical performance of the solar cells. A challenge in CPV is the design and construction of an optical system that creates a uniform illumination profile. The electrical performance of the solar cells are highly dependent on the uniformity of the illumination profile and non-uniform illumination profiles may lead to solar cell mismatch as well as power loss. Various types of concentrators can be classified according to their concentration ratio namely low, medium and high concentration systems.

- Low concentration (LCPV), where the magnification ratio is less than 10X.
- Medium concentration (MCPV), between 10X and 150X;
- High concentration, where the ratio lies above 150X, but is usually less than 1000X

Kostic et al. [3] surveyed the influence of reflectance from flat aluminum concentrators on energy efficiency of PV/Thermal collector. The flat aluminum has a simple structure and resulted in appropriate enhancement of thermal and electrical efficiency. The flat concentrators are interesting for their uniform concentration, simple structure and low cost. However, low concentration ratio (usually lower than 3) limited their application.

Mosalam-Shaltout et al. [4] studied the performance of a LCPV for a year and compared the results with the performance of simple PV system. This research showed a good improvement in PV performance which was equipped with a flat plate concentrator (V-trough). The concentration ratio at this research was about 1.6 and trough was full tracing.

An experimental and theoretical comparisons between an integrated V-trough PV system and PV panel have been investigated by Haitham at a1 [5]. The distinctive curves of the V-trough PV system have been concluded by by developing an united thermal, optical and electrical model. Improving the effectiveness of the PV system by employing less expensive reflectors could be achieved by using a good way which is common PV panel and a V-trough PV system. The power resulted is significantly improved by implementing cooling and also cooling enhance the thermal power acquired from the V-trough PV system. The thermal achievement of V-trough PV system with and without cooling is concluded by the set steady state model. Electrical and thermal achievement of the collector were submitted and researched. IT'S predicted from the results that by implementing cooling the power of V-trough is rises by 31.5% and for normal PV panel by 22.8%. IT'S found by comparing that there is a good coincidence between the numeral and experimental results. Using the outputs it could be predicted that using a V-trough PV system is more benefit able than using simple PV system so, V-trough PV systems are advisable and approved for better electric power outcome.

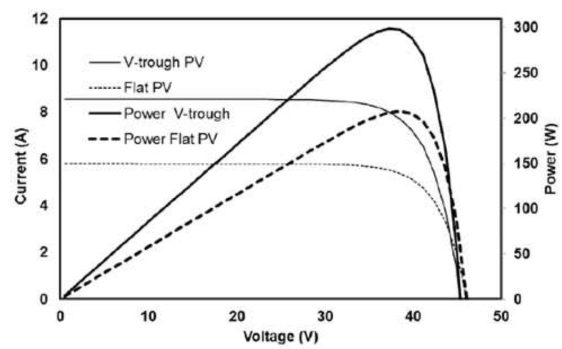

Fig 11 I-V and P-V curves for Flat PV and V-trough PV system (cooled) [5].

4.1 Concentrator V trough

The number of reflections impact the performance of the concentration factor and spread if radiation at the flat sided linear trough base. The solar beams undergo before arriving to the base, the coefficient of reflection and the cone apex. Before dealing with the rectilinear trough, the next general notes are made. At first, consider light incident is normal to the opening of the trough, which is the angle of incidence with considering the symmetry plane of the trough is zero ($\theta = 0$). consider half of the apex angle ... of the trough a then set the origin of the coordination system at the apex [3]. A beam beginning at the upper left-hand corner of a trough is presented in Figure 12. The beam will reflect and so on till after a particular number of reflections, the reflected beam points up rather than down the trough. The beam starts a path at this stage which will reflect it out if the trough. The spread of irradiance across the base in that situation is presented by the *Fig 12*at the right of the cone. Light crossing through portion of the opening, **zone II**, lightens portion of the base after two reflections; **zone I**equally full the base after one reflection and **zone 0**directly fill the PV module. So, zones are parts of the opening which could be specialized by number of reflections that undergo by incident light before arriving to the PV module.

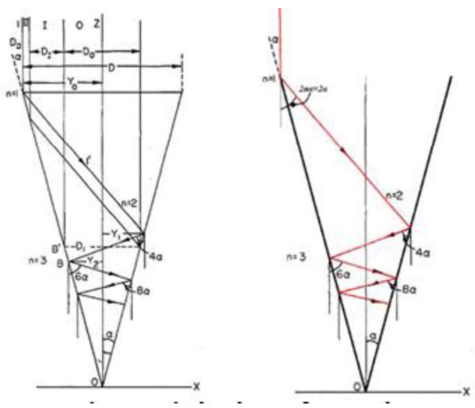

Fig 12 The ray passes downward after the n reflections for case normal incidence ($\gamma = 0$)& ($\gamma = \alpha$)[6]

4.2 Concentration factor when the normal incidence ($\psi = 0$)

For normal incidence we defined the concentration factor as the ratio of the total energy over the PV module divided by the solar insulations (σ) times the width of the PV module. Thus, in the notation of *Fig 12* with D_n the width of Zone n,

$$C = \frac{\sigma D_O \, + \, 2\sigma\rho D_{\mathrm{I}} \, + \, 2\sigma\rho^2 D_{\mathrm{II}}}{\sigma D_O} \tag{20}$$

$$C = \frac{D_O \, + \, 2\rho D_{\mathrm{I}} \, + \, 2\rho^2 D_{\mathrm{II}}}{D_O} \tag{21}$$

when $\rho = 1$ the concentration factor is just

$$C = \frac{D_O \, + \, 2 \, D_{\mathrm{I}} \, + \, 2 \, D_{\mathrm{II}}}{D_O} = \frac{D}{D_O} \tag{22}$$

which is just the ratio of the width of the entrance aperture, D to the width of the PV module, D_o. It is important to realize that when we place the PV module at B' position as shown in the *Fig 12,* we have maximized the concentration factor for the specified number of reflections.

$$C = \frac{\sin(2n+1)\alpha}{sin\alpha} \tag{23}$$

The ratio of the length of the side of the trough to the PV module width, that is, L/D_O is a measure of the amount of material needed to construct a trough of given width *Do.* L is the distance along the side of the trough, measured from the upper edge of the trough to the PV module at which the ray terminates after *n* reflections. *L* is shown in *Fig 12*for $n = 2$. From the geometry

$$L = \frac{D - D_O}{2sin\alpha} \tag{24}$$

$$\frac{L}{D_O} = \frac{sin(2n+1)\alpha - sin\alpha}{2\,sin^2\alpha} \tag{25}$$

$$C - 1 = \left[\frac{L}{D_O}\right] 2sin\alpha \tag{26}$$

$$C = \frac{2Lsin\alpha}{D_O} + 1 \tag{27}$$

4.3 Concentration factor when the incidence ($\psi \neq 0$)

The concentration factor for the specified number of reflections.

$$C = \frac{\sin[(2n+1)\alpha + \psi]}{\sin(\alpha + \psi)} \tag{28}$$

The ratio of the length of the side of the trough to the PV module width, that is, L/D_O is a measure of the amount of material needed to construct a trough of given width *Do.* L is the distance along the side of the trough, measured from the upper edge of the trough to the PV module at which the ray terminates after *n* reflections.

$$\frac{L}{D_O} = \frac{sin[(2n+1)\alpha + \psi] - \sin(\alpha + \psi)}{2\sin\alpha\sin(\alpha + \psi)} \tag{29}$$

5 EXPERIMENTAL SET-UP

The experimental setup of the present study is designed to investigate the effect of different techniques to achieve higher efficiency of a PV system. The maximum electrical power was affected by solar radiation absorbed by PV cells and the temperature generated on PV layers, the efficiency of PV modules decreases when the absorbed solar radiation decreases and when the temperature of PV cells increases, so the present cases study illustrated with Taking in consideration these parameters to enhance the efficiency of PV system. Using different cooling techniques forced air convection and water cooling to investigate the higher thermal efficiency for removal heat generation from PV layers. Using optical concentration with different angles for enhancement the absorbed solar radiation during sun rise day.

Fig 13 Two Monocrystalline photovoltaic modules with different cooling

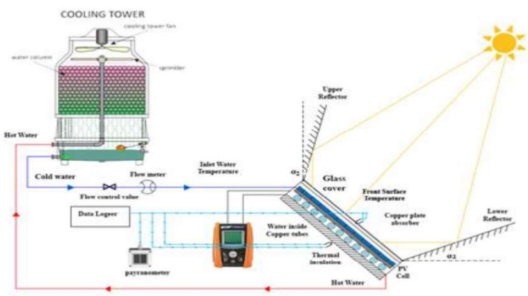

Fig 14 Schematic diagram of the PV/T system with LCPV

Table 3 Monocrystalline data sheet

Maximum Power (P_{max})	180 Wp +- 5%
Maximum Power Voltage (V_{mp})	24.6 V
Maximum Power Current (I_{mp})	7.3 A
Open Circuit Voltage (V_{oc})	30.5 V
Short Circuit Current (I_{sc})	8.05 A
Max System Voltage	800 V
Maximum series fuse rating	10 A

Aluminum reflector used to increase the amount of radiation flux falling on PV module that influence the output electrical power. The performance of the solar panel with reflector depends mainly on three parameters (angle, width and reflectivity of reflector). Using DC linear motor to setup the angle of reflectors.

Fig 15 Reflector with DC linear motor

Fig 16 A photograph of the Upper and bottom position of Reflectors setup.

6 RESULTS AND DISCUSSION

The present study is consisting of experimental of CPV system with measurements. The system is using concentration photovoltaic to improve the PV system effectiveness and at the same time decrease the expense of generating electricity. Using Aluminum reflectors with different angles for enhancement the absorbed solar radiation during sun rise day. Using different cooling techniques forced air convection and water cooling to investigate the higher thermal efficiency for removal heat generation from PV layers.

6.1 Concentrator Photovoltaics (CPV)

For the total, diffuse and specular reflectance from the flat solar radiation reflectors made of Aluminum sheets. Typical results of the change of total solar radiation intensity on PV/T collector surface measured during the sun peak on March and August depending on the positions of reflectors as shown in*Fig 14*, where α_1 denotes the angle between bottom reflector and horizontal plane, and α_2 denotes the angle between upper reflector and vertical plane as shown in *Fig 14*. From results of solar incidence, optimal positions for the upper and bottom reflector are at the angle of $\alpha_2 = 0°$, 5°, 10°, 15°, 20° and angle α_1=10°, 15°, 20°, 25°, 30°, 35°, 40°. In this study, measurements have been done in different days in March and August. The values of the optimal positions of upper and bottom reflectors for given tilted plane angle β=30, experimental measurements indicated that the best positions of bottom and upper reflectors values for a particular inclined plane, position of the upper reflector $\alpha_2$to be the range of (5 ~ 15) and the angle position of the lower reflector α_1 to be 35°.

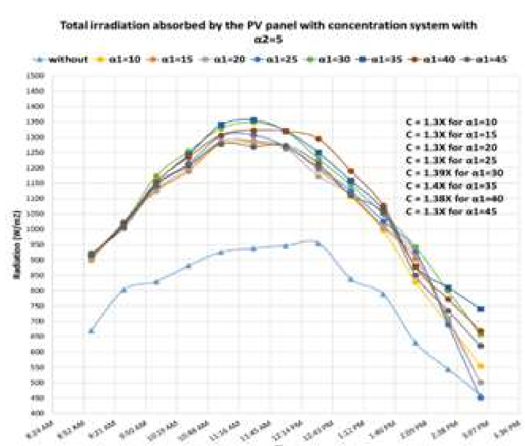

Fig 17 Absorbed irradiation with α_2=5

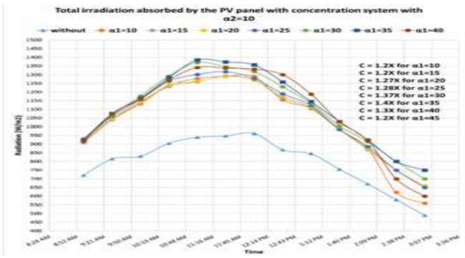

Fig 18 Absorbed irradiation with α_2=10°

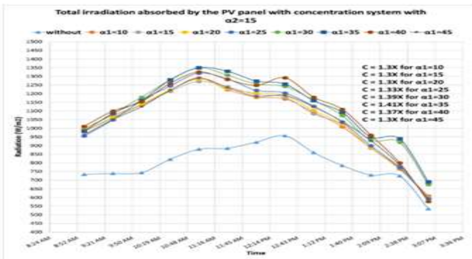

Fig 19 Absorbed irradiation with α_2=15°

Table 4 Concentration Ratio for different angles

	α2=20°	α2=15°	α2=10°	α2=5°	α2=0°
	C.R	C.R	C.R	C.R	C.R
α1=10°	1.13	1.316	1.305	1.319	1.276
α1=15°	1.14	1.315	1.3	1.334	1.305
α1=20°	1.155	1.321	1.306	1.337	1.312
α1=25°	1.176	1.339	1.318	1.348	1.332
α1=30°	1.259	1.401	1.376	1.39	1.346
α1=35°	1.26	1.413	1.389	1.387	1.339
α1=40°	1.224	1.337	1.355	1.383	1.312
α1=45°	1.189	1.3	1.317	1.34	1.285

From previous investigations of concentrations, the angles for a good agreement of concentration when the angle of upper reflector α_2 to be the range of (5 ~ 15) and the angle position of the lower reflector α_1 to be 35°, figure indicate the practical and theoretical results of concentration for the angles of reflectors.

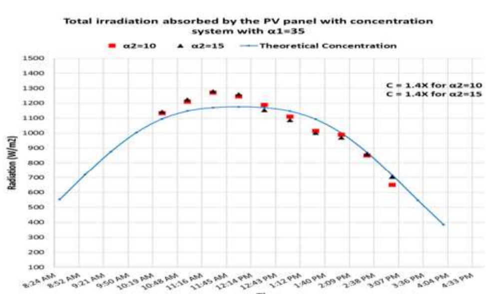

Fig 20 Theoretical and practical results for concentration

Technical and photovoltaic-cell quality comparing between V-trough PV system and integrated PV panel. implementing cooling improved the power resulted significantly and thermal acquired from the V-trough PV system.

The thermal achievement of V-trough PV system with and without cooling is concluded by the set steady state model. Electrical and thermal achievement of the collector were submitted and researched.

Applying cooling impact in PV system, the power of PV is rises by 31.5% and for normal PV panel by 22.8%.Investigation a pretty coincidence of results by measuring at any time of the year during sun rise. Using the outputs, it could be predicted that using a V-trough PV system with cooling is more benefitable than using simple PV system so, V-trough PV systems are advisable and approved for better electric power outcome.

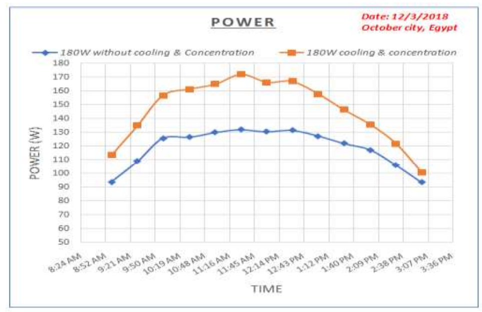

Figure 21Electrical output power of 180W modules at 12 March,2018

Optical modeling of V-trough was increasing the amount of radiation absorbed. Subsequently the temperature of the module was also rises which was concluded by thermal model. Active coolingwater technique and the performance of V-trough modeling improves the electrical power of PV modules. water cooling presents a good substitution to air cooling using coolants making more effective using of the captured thermal energy. Applying cooling impact in PV system, the normal PV panel power was raised by 22.8% and for V-trough by 31.5%. Investigation a pretty coincidence of results by measuring at any time of the year during sun rise. Using the outputs, it could be predicted that using a V-trough PV system with cooling is more benefit able than using simple PV system so, V-trough PV systems are advisable and approved for better electric power outcome.

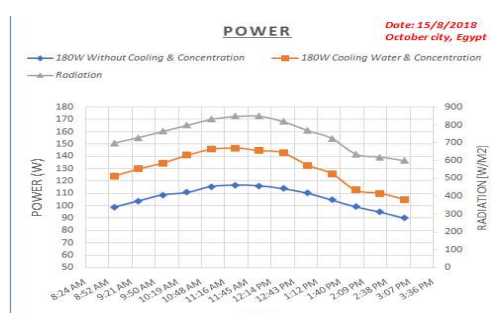

Fig 22 Electrical output power of 180W modules at 15 August,2018

CONCLUSION

The operating temperature with incidence solar radiation of photovoltaic panels represents an important parameter that influences their conversion efficiency. The present study is consisting of experimenting different techniques of cooling systems with CPV system and investigate a good agreement of results by measuring at any time of the year during sun rise. The system is using concentrated photovoltaic to improve the effectiveness of the PV panel, therefore, decrease the expense of generating electricity.Typical results of the change of total solar radiation intensity on PV/T collector surface measured during the sun peak on March and August depending on the positions of reflectors, Where $\alpha_1$indicates the angle between horizontal plane and bottom reflector. $\alpha_2$indicates the angle between vertical plane and upper reflector. From results of solar incidence, optimal positions for the upper and bottom reflector are at the angle of α2 = 0°, 5°, 10°, 15°, 20° and angle α1 =10°, 15°, 20°, 25°, 30°, 35°, 40°. In this study, measurements have been done in different days in March and August. The best positions of bottom and upper reflectors for particular inclined plane Angel β=30, experimental estimation denoted optimal Angel position of lower reflector α_1 to be 35 and the angle position of the upper reflector α_2 to be in the range of (5~15).

NOMENCLATURE

- C Concentration factor.
- D_o Width of PV module.
- D_I Width of strip at aperture that passes rays that undergo one reflection before reaching the PV module.
- D_{II} Width of strip at aperture that passes rays that undergo two reflections before reaching the PV module.
- DS Daylight Saving (it is either 0 or 60 min).
- G_{0n} Equation of time
- E Extraterrestrial radiation incident on the plane normal to the radiation on the *n*th day of the year.
- G_{sc} Solar constant radiation; 1367 W/m^2.
- H Monthly average daily radiation on horizontal surface.
- Ho Daily extraterrestrial radiation for the location averaged.
- khr Hourly clearness index.
- n Reflections occur for some of the rays entering the trough.
- $\bar{n}$ Monthly average daily hours of bright sunshine.
- $\bar{N}$ Monthly average of maximum possible daily hours of bright sunshine.
- ω Solar hour angle.

Greek Letters

- α Half of apex angle of trough.
- α_s Solar altitude angle.
- β Inclination angle or Slope of PV.
- γ Surface azimuth angle.
- γ_s Solar azimuth angle.
- θ_z Zenith angle.
- ϕ Latitude (The angular location north or south of the equator).
- δ Declination angle.
- σ Solar insolation.
- ρ Reflection coefficient of the sides of the trough.
- ψ Acceptance angle.

REFERENCES

[1] Y. A. Cengel and M. A. Boles, Thermodynamics an engineering approach, New York: McGraw-Hill Education, 2015.

[2] J. A. Duffie and W. A. Beckman, Solar engineering of thermal processes, John Wiley \& Sons, 2013.

[3] L. T. Kostic, T. M. Pavlovic and Z. T. Pavlovic, "Influence of reflectance from flat aluminum concentrators on energy efficiency of PV/Thermal collector," *Applied Energy,* vol. 87, pp. 410-416, 2010.

[4] M. M. Shaltout, A. Ghettas and M. Sabry, "V-trough concentrator on a photovoltaic full tracking system in a hot desert climate," *Renewable energy,* vol. 6, pp. 527-532, 1995.

[5] H. M. Bahaidarah, B. Tanweer, P. Gandhidasan and S. Rehman, "A combined optical, thermal and electrical performance study of a V-trough PV system—experimental and analytical investigations," *Energies,* vol. 8, pp. 2803-2827, 2015.

[6] D. G. Burkhard, G. L. Strobel and D. R. Burkhard, "Flat-sided rectilinear trough as a solar concentrator: an analytical study," *Applied Optics,* vol. 17, pp. 1870-1883, 1978.