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Calculation of the Total Solar Radiation for City of Nasiriyah per Month during the Year

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Abstract:

Solar energy is the sun-emitting light and heat that man has used a wide variety of developing technologies since ancient times techniques for solar energy include the use of solar thermal energy, whether for direct thermal heating or as part of the process of mechanical conversion for movement or electric energy, or the use of photovoltaic panels for electricity through photovoltaic panels.

Alongside secondary energy sources like wind energy, wave energy, hydroelectric power and biomass, most of the renewables accessible on the Earth's surface are attributable to solar radiation. It should be pointed out that in our lives just a little of the solar energy accessible has been utilized Solar energy produced by heat engines or photovoltaic converters produces electricity .electricity only human genius regulates its applications after solar energy is transformed into electric power heating and cooling systems in architectural designs depending on the exploitation of solar energy are among the applications created utilizing solar energy. Drinking water, sunshine, water heating, solar cooking and heating for industry uses, during distillation and disinfection .In general, solar technologies are described as passive solar energy systems or passive solar energy systems depending on how sunlight is used, processed and dispersed. The use of photovoltaic panels and a solar thermal collector with mechanical and electrical equipment for converting sunlight into other usable energy sources are technologies that rely auf the use of positive solar energy .this is done by using passive solar energy to direct a structure to the sun, use materials with the corresponding thermal mass or light disseminating characteristics and create spaces , which circulate the air naturally. In this research, the total solar energy calculations for the city of "Nasiriya" are found from the total direct and dispersed energy as well as reflected through its own laws, and the geographical location and the angles of inclination of solar radiation and the angles of inclination of the receiving solar complex to the sun for three times during a day in every month over the course of The year is in addition to the ground reflectivity factor, and some other factors such as clouds, humidity, dust and smoke have been excluded from the calculations.

Keywords: Total solar radiation ,the tilt angle , Solar altitude angle, Solar incident angle.

1. Introduction:

Solar energy is defined as the energy resulting from converting sunlight into electricity through the use of photovoltaic solar cells **[1].**

It is one of the most important sources of renewable energy, and the fastest growing among them, It promises a promising future in providing energy for various uses.

The sun is the world's most abundant source of energy, we may directly and indirectly use the sun (as in solar heating), The major advantage of solar energy is that everywhere sunlight is free of charge,

First of all we are investing significant energy to create electricity or convert solar energy into another energy form, but the primary advantages is that no maintenance for 40 to 50 years after installation is needed.

It is a vital energy source, and its methods are widely described as passive solar or active solar depending on how solar sunlight is captured, distributed or transformed into solar power .the great amount of accessible solar energy makes it a very attractive electrical source.

As for the solar thermal collector, it is a complex that is designed to collect heat by absorbing sunlight, and the collector is a device that aims to convert the thermal energy contained in sunlight or solar radiation into a more usable and storage form.

The amount of solar energy that hits the surface of the earth is about 1000 watts per square meter under the clear sky, and this depends on the weather conditions, the location and the direction of the surface.

However, the word "solar thermal collector" can apply to both more complicated solar thermal concentrating and accumulating systems like parabolic devices, solar troughs and solar towers, as well as less complex installations like solar air heating and updraft tower solar.

Solar power plants often employ more complicated collectors to create electricity by heating water to produce steam, which powers a turbine that drives an electric generator.

For extra heating of structures perpendicular to the sun's rays, less sophisticated collectors are commonly employed in residential and commercial buildings. and the types of solar collectors used to generate energy. This section's parabolic troughs, bowls and towers are nearly all employed in solar power plants or for research These solar concentrators, despite their simplicity, are still far from reaching their theoretical maximum concentration. Of course, we won't be able to use solar electricity at night. As a result, energy storage is critical since contemporary power systems require a constant power source **[2].**

Rechargeable batteries are commonly used to store surplus power in off-grid solar equipment. Excess power can be transmitted to the transmission network when devices are linked to the network. Grid metering software informs these devices about how much power they're supplying to the grid. This statement corresponds to the electricity delivered by the network when the device's electrical requirements are not met, and the network is used as a storage media.

-As for the advantages of solar energy **[3]:**

1) Renewable energy is well and permanently present in all parts of the world, and is renewable again.

2) It is environmentally friendly and clean, and limits the accumulation of waste in all its forms.

3) It is easy to use using simple techniques and mechanisms, and it can be manufactured locally in developing countries.

4) It is very economical.

5) Help create new job opportunities.

6) It helps reduce the damages of gaseous and thermal emissions, and prevents harmful acid rain.

7) Clearing crops of chemical pollutants, thus increasing agricultural productivity.

-As for its disadvantages, they are:

1) The efficiency of solar cells is estimated at only about 20%.

2) The high cost of solar energy storage batteries, as well as the difficulty of storing this energy without losing substantial amounts of it.

3) The cost of installing a solar system is approximately the same, but it is more cost-effective to consume that energy over time.

4) Solar energy is scarce during the day, and its availability or absence varies with the seasons.

5) The high cost of equipment that converts heat energy from the sun into electrical energy or electromagnetic energy.

Here is a summary of some of the research that talked about this topic:

The theoretically calculated amount of solar rays for the city of Nasiriyah (0-945) watts per square meter presented a study that includes special mathematical methods for calculating the amount of total solar radiation falling on the horizontal surface of the city of Nasiriyah per unit area, which can be applied on the ground in order to use photovoltaic panels to obtain the electrical energy needed to feed the required loads. Weather data was based on temperature, relative humidity, dust and clouds for the period from(1\1/2007-1/1/2008) And taken from the Nasiriyah meteorological station, which is located on longitude (46) degrees and latitude (31) degrees, which has a direct impact on the angle of incidence of solar radiation **[4].**

A mathematical model to estimate the total solar radiation falling on the horizontal surface as a function of each of the relative humidity, average temperatures and the ratio of brightness, and the model gave high accuracy in the application Schemes of spatial variation of total solar radiation during the months of winter, spring, autumn and summer in Iraq were found through 17 tropical stations distributed over the different regions of the country, the monthly averages of total solar radiation falling on the horizontal surface for all of Iraq ranged between (6842, 2307) W/m² During the months of the year, the annual spatial variation of total solar radiation in Iraq explained the gradual increase in the values of total solar radiation as we moved from north to south **[5].** In Baghdad, statistics for solar collector arrays that were optimized theoretically were collated for each month. The maximum solar radiation in the clear sky per unit area per day was calculated using MATLAB software, and the tabular data was used to create an economically conserved design of solar collector or surface collector systems. The results showed that the shading effect on the arrays of plates almost fades at a space between two plates rows to plate height ratio greater than 1 in summer and greater than 2 in winter **[6].**

The potential for implementing concentrated solar power technology to boost electricity generation in Iraq is discussed in this paper. Solar energy is currently underutilized in Iraq. In addition, the study discusses Iraq's limited current solar energy activities, as well as the Iraqi government's attempts to use solar energy. Two approaches for utilizing concentrated solar power have been proposed to support existing thermal power generation, with the possibility of being implemented as standalone plants or being integrated with thermal power plants; however, the cost analysis has shown that for 50 kW concentrated solar power in Iraq, the cost of 50 kW concentrated solar power in Iraq is higher than the cost of 50 kW concentrated solar power in the United States **[7].**

The research is conducted on real-time solar PV panels with a 5 kWp rated capacity installed at 10°, 20°, 25°, 30°, and 40° angles on the rooftop of an engineering institute in Chandigarh, India. The real-time power generation response for a year is used to determine the optimal tilt angle, and the results obtained from the practical setup are validated by comparing them to the regression analysis simulation results. The influence of the ideal angle on total power output and carbon emissions is also examined. The results show that the suggested technique is highly successful in increasing the power generation of PV panels by 7–8% and can be implemented nearly anywhere in the world **[8].**

Theoretical Analysis:

In this research, ASHRAE's clear sky model on inclined A, B and C surfaces is employed.

The model comprise the direct evaluation and diffuse radiations calculated following the determination of the Position and time of the solar system **[7]:**

Solar angle and angle of incidence calculation:

The solar angle (Ψ) and the incidence angle (θ) are [1] :

$$\sin \Psi = \cos \emptyset_L \cos \delta \cos \omega + \sin \emptyset_L \sin \delta \quad \text{.... (1)}$$

$$\cos \theta = \cos\Psi \cos \gamma \sin \beta + \sin\Psi \cos \beta \quad \text{......(2)}$$

Where:

$ø_L$: latitude angle of the location (31.054 for Nasiriyah)

β: tilt angle of the surface (It is the same as the latitude angle)

δ: solar declination angle, Duffie and Beckman estimated it as a function of the number of days in the year. [2]as:

$$\delta = 23.45\,[360 * (284 + N)/365] \quad \text{..... (3)}$$

The hour angle ω (degrees), computed using the following formula:

$$\omega = 15 * (\mathrm{LAT} - 12) \quad \text{...... (4)}$$

Where: LAT is the local time

and γ_s is the surface azimuth angle (equal zero for south direction), It can be determined and calculated through the following law:

$$\sin(\gamma_s) = (\cos(\delta) \sin(\omega)/\cos(\Psi)) \quad \text{...... (5)}$$

Calculate of direct normal solar radiation:

direct normal solar radiation I_{DN} is [3] :

$$I_{DN} = A/exp\,(B/sin\,\Psi) \quad \text{........ (6)}$$

Where:

A: apparent solar radiation (W/m2),

B: atmospheric extinction coefficient.

The values of A and B calculated by Joudi [4] :

$$A = 1158\,[1 + 0.066\,cos\,(360 * N/370)] \quad \text{........ (7)}$$

$$B = 0.175\,[1-0.2\cos(0.93N)]-0.0045\,[1-\cos(1.85N) \quad \text{..(8)}$$

Calculation of the total, direct and diffuse and reflected radiation:

To find the component of direct radiation on a surface for a incident angle [1]:

$$I_D = I_{DN} \cos(\theta) \quad \text{....... (9)}$$

And Farber and Morrison [5] to find the diffuse solar radiation (Id) :

$$I_d = C\, I_{DN}\, F_{ss} \quad \text{...... (10)}$$

C diffuse to direct normal average ratio that calculated according to Joudi [4] (dimensionless):

$C=0.0965*[1-0.42\cos(360N/370)]-0.0075[1-\cos(1.95N)]$ ….(11)

And (F_{ss}) The angle coefficient between the sky and the receiving surface of the solar radiation is calculated from :

$F_{ss}=(1+\cos(\beta))/2$ ……. (12)

As for the solar radiation reflected from the surface of the earth on the surface, it can be measured using the following law:

$I_R = I_{TH}\,\rho\,F_{sg}$ …… (13)

Where:

I_{TH}: It is the radiation falling on the surface of the reflector (the ground) and it can be calculated by:

$I_{TH} = I_{DN}(C + \sin(\Psi))$ … (14)

ρ= Earth's reflection coefficient of solar radiation.

F_{sg} =I t is the coefficient of the angle between the earth's surface and the radiation receiving surface, and it can be calculated from:

$F_{sg}=(1-\cos(\beta))/2$ …… (15)

Finally, the total solar radiation falling on the surfaces can be calculated through the following law:

$I_T = I_D + I_d + I_R$ …… (16)

Calculation procedure:

The values are found through the calculations of the previous laws to find the total incident radiation.

Where we find the value of (n), which represents the number of the day in the year, which begins with the first day of January, whose value is (1), and ends on the (31st) of December, whose value is (365).

To calculate the value of the declination angle of the sun from the equator, it can be calculated through equation No. (3) and its value is confined between (+23.45 / -23.444) and is measured in degrees.

Then find the local time for the area in the (24-hour) system, which is three times (8 am,1pm, 5 pm)

To find the angle of the solar time from equation No. (4).

From equation No. (1) we find the angle between the incident solar radiation and the horizontal plane of the Earth's surface.

Then we find the horizontal solar azimuth angle from Equation No. (5), which is the horizontal angle between the projection line of solar radiation (falling on the surface of the Earth) and the line Connecting to the south direction (and horizontally to the surface of the earth)

In the calculations, the angle of inclination of the receiving surface of the sun is taken as the same as the angle of latitude Which is (31.054)

Then we find the angle of solar incidence from equation No. (2).Then we find the direct solar radiation from equation No. (9), but before it we find the normal direct solar radiation from equation No. (6), as well as the values of the apparent solar radiation coefficient from equation (7)

and the atmospheric weather extinction coefficient from equation (8).

Then we find the diffuse solar radiation from equation No. (10),

as well as the diffusion coefficient of solar radiation from equation (11)

as well as the angle coefficient between the sky and the surface receiving solar rays from equation (12) Then we find the third type of solar radiation, which is reflected from the surface of the earth on a specific surface from equation No. (13),

It is the product of multiplying the radiation falling on the surface of the reflector (the Earth) extracted from equation (14) by the coefficient of the angle between the surface of the earth (the reflector of rays) and the surface of the receiver of the rays (the reflected radiation) calculated from equation (15), as well as multiplied by the factor of the reflection of the earth for solar radiation, which we have taken the average surface of the earth (0.3) **[9].**

Finally, we find the total radiation, which is the sum of the direct, diffuse and reflected radiation from the previous equations **[10].**

Results and discussion:

As for the results in the graphs, the angle of the sun's inclination from the equator is its maximum point in the middle of summer and gradually decreases in the winter as shown in Figure (5-1) for three times during the day because this angle depends on the number of days in the year(n).

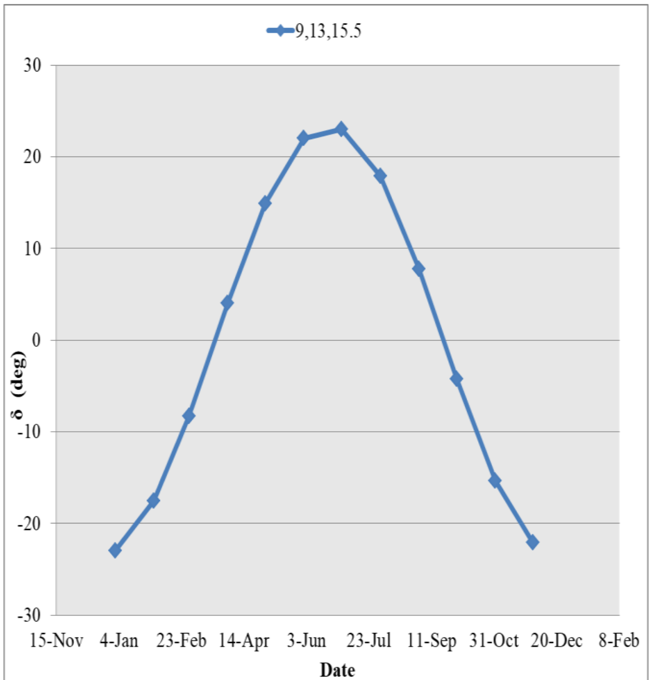

Fig.(5-1): solar declination angle in all position

The angle of solar elevation is at its peak at one in the afternoon in the middle of summer and gradually decreases until the middle of winter, and its lowest value is at (3:30) in the evening, as it increases in the middle of summer and decreases in the middle of winter as shown in Figure (5-2).

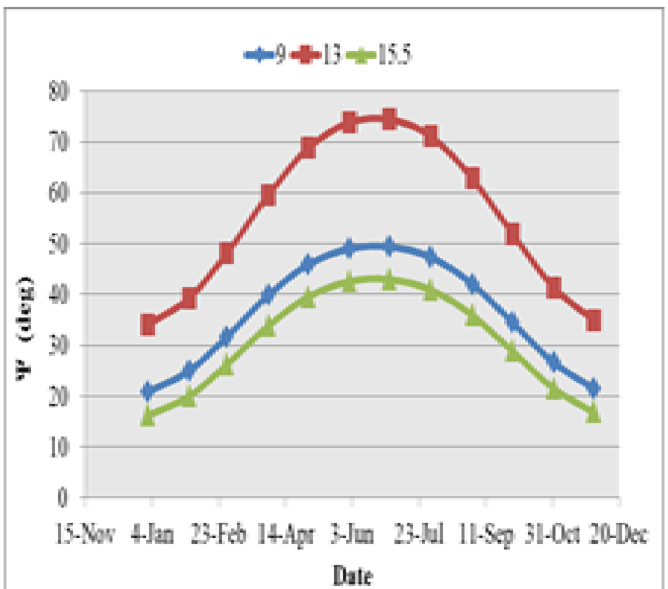

fig.(5-2): Solar altitude angle in the Nasiriyah city

Figure (5-3) shows the values of the angle of incidence of solar radiation throughout the year, where the highest value is at (3:30) in the evening and the lowest value at one o'clock in the evening.

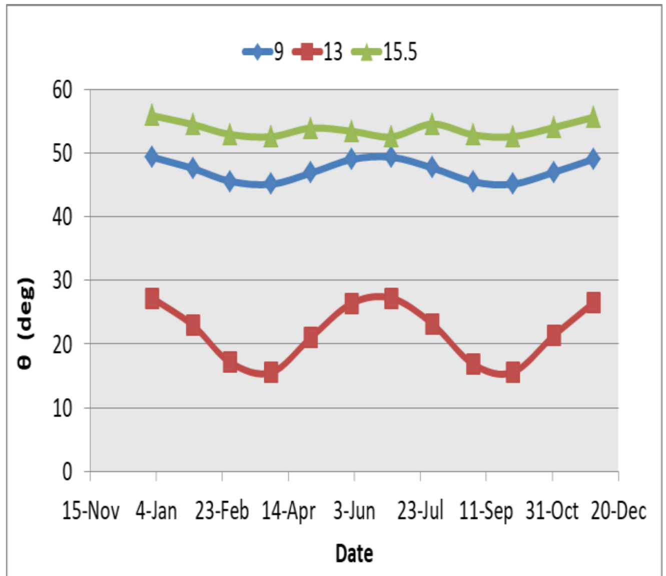

fig.(5-3): Solar incident angle in the Nasiriyah city

Therefore, the results of the total solar radiation were high throughout the year at one in the afternoon, while it was less than at nine in the morning, while the lowest at (3:30) in the evening, as shown in the figure. (5-4).

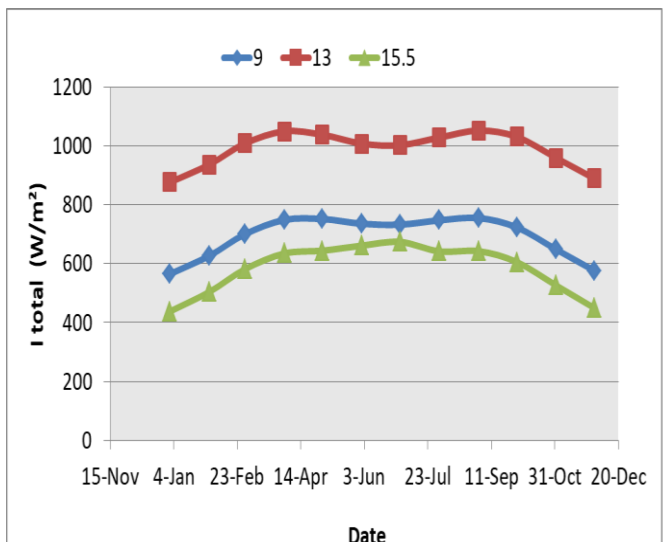

fig.(5-4): Total Solar radiation in the Nasiriyah city

Conclusion:

It is concluded from this study that it is possible to benefit from the amount of solar energy that reaches the earth in several applications, most notably the generation of electric power through solar energy collectors and storing it in energy storage depots for later use at night and on cloudy days.

The most benefit is in the summer, especially in the hot regions that are located near the equator, as in Nasiriyah and Kampala, and in contrast to the rainy regions with many clouds and dense fog, as well as short daylight hours, which are located in the north of the globe, where the efficiency of solar energy is low, and energy collectors Solar is useless and its losses are greater than its profits.

It is concluded from the previous tables and graphs that if the angle of inclination of the sun is positive, this means that the north pole of the earth is closest to the sun, while if the value of the angle is negative, this means that the south pole of the earth is closest to the sun.

It can also be said that when the value of the sun's declination from the equator is positive, it means that the summer has occurred in the northern hemisphere while the winter has occurred in the southern hemisphere at the same time, and if the angle is negative then the seasons are vice versa.

It is also concluded from the calculations that the angle of the solar time is negative in the east (ie morning) and zero in the middle of the day, while it is positive in the west of the globe (ie evening).

It is also noted that the horizontal solar azimuth has a negative value from sunrise to midday (south), where it is zero at midday (south), after which its value is positive for sunset (west).

Table 1 Calculation of the Nasiriyah city:

date	N	δ	LAT	ω	ϕ	sin Ψ	Ψ	sin ɣ	ɣ	β	cos θ	θ
1-Jan	1	-23	9	-45	31.054	0.356053	20.85799	-0.69654	-44.1503	31.054	0.650895	49.39087
1-Jan	1	-23	13	15	31.054	0.560152	34.06633	0.287599	16.71428	31.054	0.889139	27.2347
1-Jan	1	-23	15.5	52.5	31.054	0.2785	16.17069	0.760369	49.4967	31.054	0.560368	55.91876
1-Feb	32	-17.5165	9	-45	31.054	0.422417	24.98726	-0.74395	-48.0691	31.054	0.674318	47.59875
1-Feb	32	-17.5165	13	15	31.054	0.633861	39.33555	0.319114	18.60934	31.054	0.921136	22.90725
1-Feb	32	-17.5165	15.5	52.5	31.054	0.342073	20.00321	0.805137	53.62348	31.054	0.580533	54.51194
1-Mar	60	-8.3	9	-45	31.054	0.524955	31.6652	-0.82208	-55.294	31.054	0.6997	45.59703
1-Mar	60	-8.3	13	15	31.054	0.744358	48.10398	0.383521	22.55197	31.054	0.955809	17.09698
1-Mar	60	-8.3	15.5	52.5	31.054	0.441587	26.20516	0.874975	61.04198	31.054	0.602385	52.95909
1-Apr	91	4	9	-45	31.054	0.640273	39.8122	-0.91829	-66.6778	31.054	0.705384	45.1394
1-Apr	91	4	13	15	31.054	0.861459	59.48076	0.508418	30.55849	31.054	0.963573	15.51234
1-Apr	91	4	15.5	52.5	31.054	0.556228	33.79533	0.952337	72.23902	31.054	0.607279	52.60702
1-May	121	14.9	9	-45	31.054	0.718038	45.89273	-0.98179	-79.0496	31.054	0.683331	46.8955
1-May	121	14.9	13	15	31.054	0.932308	68.79752	0.69157	43.7545	31.054	0.933448	21.02122
1-May	121	14.9	15.5	52.5	31.054	0.63662	39.54025	0.994165	83.80743	31.054	0.588292	53.96407
1-Jun	152	22	9	-45	31.054	0.754895	49.0162	-0.99965	-88.4903	31.054	0.655618	49.03347
1-Jun	152	22	13	15	31.054	0.960475	73.83734	0.862079	59.55084	31.054	0.895591	26.41558
1-Jun	152	22	15.5	52.5	31.054	0.676779	42.59247	0.999183	87.68338	31.054	0.595135	53.47777
1-Jul	182	23	9	-45	31.054	0.759167	49.39081	-1	-89.9094	31.054	0.650895	49.39087
1-Jul	182	23	13	15	31.054	0.963266	74.42211	0.887156	62.51807	31.054	0.889139	27.2347
1-Jul	182	23	15.5	52.5	31.054	0.681614	42.96988	0.99805	86.42164	31.054	0.607484	52.5922
1-Aug	213	17.9	9	-45	31.054	0.734991	47.30649	-0.99233	-82.9014	31.054	0.672879	47.71035
1-Aug	213	17.9	13	15	31.054	0.945984	71.08211	0.759658	49.43405	31.054	0.91917	23.19501
1-Aug	213	17.9	15.5	52.5	31.054	0.654819	40.90593	0.998895	87.30628	31.054	0.579294	54.5991
1-Sep	244	7.725	9	-45	31.054	0.669607	42.03674	-0.94342	-70.6333	31.054	0.70069	45.51765
1-Sep	244	7.725	13	15	31.054	0.88932	62.78796	0.560854	34.11489	31.054	0.95716	16.83165
1-Sep	244	7.725	15.5	52.5	31.054	0.586121	35.88222	0.970292	75.9991	31.054	0.603237	52.89794
1-Oct	274	-4.216	9	-45	31.054	0.566203	34.48586	-0.85554	-58.8196	31.054	0.705193	45.15483
1-Oct	274	-4.216	13	15	31.054	0.787328	51.93654	0.418661	24.75008	31.054	0.963312	15.56813
1-Oct	274	-4.216	15.5	52.5	31.054	0.48218	28.82789	0.903129	64.57252	31.054	0.607114	52.61887
1-Nov	305	-15.3634	9	-45	31.054	0.44745	26.58019	-0.76242	-49.6779	31.054	0.681838	47.01255
1-Nov	305	-15.3634	13	15	31.054	0.661252	41.39543	0.332687	19.43198	31.054	0.931408	21.34458
1-Nov	305	-15.3634	15.5	52.5	31.054	0.36621	21.48207	0.822113	55.29688	31.054	0.587007	54.05508
1-Dec	335	-22.11	9	-45	31.054	0.367062	21.53454	-0.70427	-44.7705	31.054	0.655108	49.07214
1-Dec	335	-22.11	13	15	31.054	0.572482	34.92352	0.292452	17.0048	31.054	0.894894	26.50512
1-Dec	335	-22.11	15.5	52.5	31.054	0.289007	16.79851	0.767776	50.15457	31.054	0.563995	55.66747

A	B	C	IDN	ID	Fss	Id	ITH	Fsg	ρ	IR	Itotal
1149.1	0.1656	0.1219	721.7183	469.763	1	87.97746	344.9474	0.07166	0.3	7.415679	565.1561
1149.1	0.1656	0.1219	854.9991	760.2134	1	104.2244	583.1541	0.07166	0.3	12.53665	876.9744
1149.1	0.1656	0.1219	634.045	355.2984	1	77.29008	253.8715	0.07166	0.3	5.457729	438.0462
1149.6	0.1659	0.1221	776.2147	523.4159	1	94.77582	422.6619	0.07166	0.3	9.086385	627.2781
1149.6	0.1659	0.1221	884.8693	815.0851	1	108.0425	668.9265	0.07166	0.3	14.38058	937.5082
1149.6	0.1659	0.1221	707.8164	410.911	1	86.42438	328.5491	0.07166	0.3	7.063148	504.3986
1150.1	0.1661	0.1223	838.1491	586.4533	1	102.5056	542.4961	0.07166	0.3	11.66258	700.6215
1150.1	0.1661	0.1223	920.0784	879.4187	1	112.5256	797.3932	0.07166	0.3	17.14236	1009.087
1150.1	0.1661	0.1223	789.548	475.612	1	96.56172	445.2156	0.07166	0.3	9.571244	581.7449
1150.6	0.1664	0.1225	887.2704	625.8666	1	108.6906	676.7861	0.07166	0.3	14.54955	749.1068
1150.6	0.1664	0.1225	948.4965	913.9455	1	116.1908	933.2813	0.07166	0.3	20.06368	1050.2
1150.6	0.1664	0.1225	853.1035	518.0714	1	104.5052	579.0251	0.07166	0.3	12.44788	635.0245
1151.2	0.1666	0.1227	912.8203	623.7585	1	112.003	767.4426	0.07166	0.3	16.49848	752.26
1151.2	0.1666	0.1227	962.8175	898.7397	1	118.1377	1015.78	0.07166	0.3	21.83725	1038.715
1151.2	0.1666	0.1227	886.1317	521.3046	1	108.7284	672.8577	0.07166	0.3	14.46509	644.4981
1151.7	0.1669	0.1229	923.2537	605.3017	1	113.4679	810.4275	0.07166	0.3	17.42257	736.1922
1151.7	0.1669	0.1229	967.9944	866.9269	1	118.9665	1048.701	0.07166	0.3	22.54498	1008.438
1151.7	0.1669	0.1229	899.9913	535.616	1	110.6089	719.7043	0.07166	0.3	15.4722	661.6972
1152.2	0.1671	0.1231	924.5607	601.7922	1	113.8134	815.7093	0.07166	0.3	17.53612	733.1417
1152.2	0.1671	0.1231	968.7011	861.3104	1	119.2471	1052.364	0.07166	0.3	22.62373	1003.181
1152.2	0.1671	0.1231	901.6937	547.7645	1	110.9985	725.6054	0.07166	0.3	15.59906	674.362
1152.8	0.1674	0.1233	917.9944	617.699	1	113.1887	787.9068	0.07166	0.3	16.93842	747.8262
1152.8	0.1674	0.1233	965.8326	887.7639	1	119.0872	1032.749	0.07166	0.3	22.20205	1029.053
1152.8	0.1674	0.1233	892.7494	517.1643	1	110.076	694.6653	0.07166	0.3	14.93391	642.1742
1153.3	0.1676	0.1235	897.9251	629.1667	1	110.8937	712.1507	0.07166	0.3	15.30981	755.3703
1153.3	0.1676	0.1235	955.2032	914.2821	1	117.9676	967.4492	0.07166	0.3	20.79822	1053.048
1153.3	0.1676	0.1235	866.4764	522.6904	1	107.0098	614.8698	0.07166	0.3	13.21847	642.9187
1153.8	0.1679	0.1236	857.7213	604.8594	1	106.0144	591.6586	0.07166	0.3	12.71948	723.5932
1153.8	0.1679	0.1236	932.2148	898.0137	1	115.2218	849.1809	0.07166	0.3	18.25569	1031.491
1153.8	0.1679	0.1236	814.5257	494.5101	1	100.6754	493.4235	0.07166	0.3	10.60762	605.7931
1154.4	0.1681	0.1238	792.8638	540.6049	1	98.15654	452.9234	0.07166	0.3	9.736947	648.4984
1154.4	0.1681	0.1238	895.2664	833.8585	1	110.834	702.8307	0.07166	0.3	15.10945	959.802
1154.4	0.1681	0.1238	729.4638	428.2005	1	90.30762	357.4445	0.07166	0.3	7.684343	526.1925
1154.9	0.1684	0.124	729.9609	478.2034	1	90.51515	358.4561	0.07166	0.3	7.706089	576.4247
1154.9	0.1684	0.124	860.5843	770.1321	1	106.7125	599.3819	0.07166	0.3	12.88551	889.7301
1154.9	0.1684	0.124	644.8928	363.7162	1	79.9667	266.3452	0.07166	0.3	5.725889	449.4088

Nomenclature:

N	Day number in the year
LAT	local time
A	Apparent solar radiation (W/m^2).
B	atmospheric extinction coefficient
C	Average ratio of diffuse to direct normal radiation
I_{DN}	Direct normal solar radiation(W/m^2)
I_D	direct radiation(W/m^2)
I_d	Diffuse radiation(W/m^2)
I_R	reflected radiation(W/m^2)
I_{TH}	radiation falling on the surface of the reflector(W/m^2)
I_T	Total radiation(W/m^2)
F_{sg}	coefficient of the angle between the earth's surface and the radiation receiving surface
F_{ss}	The angle coefficient between the sky and the receiving surface of the solar radiation

Greek symbols:

Ψ	Altitude angle (degree)
β	Collector tilt angle (degree)
γ_s	Surface azimuth angle (degree)
δ	Declination angle (degree)
$Ø_L$	Latitude angle (degree)
θ	Incidence angle (degree)
ω	Hour angle (degree)
ρ	Earth's reflection coefficient of solar radiation

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