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Simulation and Estimation of a Daily Global Solar Radiation in Egypt

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Abstract: In this paper a study has been made to estimate average global radiation using hours of bright sunshine and calculated solar radiation data available for different locations in Egypt.An empirical model is proposed for estimating daily global solar radiation on a horizontal and on a tilted, south-facing surface by the days of the year.Also, presents the implementation of a generalized solar radiation simulation model using MATLAB/GUI interface. The model is developed using basic equations of the solar radiation including effects of time change and different location of sites. The present study was carried out for the provinces and main cities of Egypt. The amount of hourly, monthly and yearly average of daily solar radiation are computed and discussed.This database contains normal direct and global horizontal irradiances as well as diffuses irradiance on a horizontal plane and an inclinedplane. Results obtained are useful for any solar energy system applications in Egypt.

Key words: Solar radiation · Egypt · Simulation · MATLAB

INTRODUCTION

Egypt lies on the north eastern side of Africa, bordered on its northern coast by the Mediterranean Sea and on its eastern coast by the Red Sea. It comprises an area of about one million km^2, made up as follows: Nile valley and delta about 4% of the total; Eastern desert area about 22%; Western desert area about 68%; and the Sinai Peninsula area about 6% [1]. There is a trend in Egypt to apply photovoltaic power plantsand solar thermal power plants to meet the requirements of industry, tourism, petroleum, electricity, health and reconstruction. It is well known that Egypt region has significant and unique importance due to its certain strategic site near the North Eastern borders of Africa. Solar energy applications in the field of photovoltaic and solar thermal application requires a complete knowledge and detailed analysis about the potentiality of the site for solar radiation activity. The aim of this paper is to design a basic study for solar radiation calculations and data that will help designers and engineers interested in solar energy and photovoltaic applicationsin Egypt.The present study was carried out for the provinces and different sites of Egypt.

Fluctuating oil prices and the uncertainties of future supplies have led to aresonance of interest in alternative energy sources. For countries such as Egypt, solar energy is a potential alternative to oil orcoal based sources of electric energy. They are especially appropriate in remotelocations not connected to the grid network, such as different places in remote and rural areas in Egypt, where most electrical energy is derived by diesel generators [2].

The solar radiation data is one of the most important indicators for photovoltaic (PV) power generation application. It is utilized frequently for system capacity plan, operation and dispatch, reliability evaluation, system modelling and simulation of photovoltaic power station.Effective selection of a photovoltaic or solar thermal power plants location depends on considering several independent factors concerning solar radiation,geomorphology and wind speed. The present study uses a basic equations method and simulate it using Matlabto make appropriate site selections in order to achieve sustainable development by effective solar radiation site. Solar radiation data was simulated by MATLAB/GUI interface software[3] and the results are discussed. The simulation selecting the best site with best solar radiation data for photovoltaic power plants or solar thermalpower plants to have an optimize system according to solar radiation data for sites.

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El-Sebaii *et al*. [4] calculated of horizontal diffuse and inclined total monthly average daily solar radiation in Jeddah. They used both Liu and Jordan [5] isotropic model and Klucher's anisotropic model [6]. Zang *et al*. [7] estimated typical solar radiation data from both measured data and synthetic generation for 35 stations in six different climatic zones of China. Rodriguez *et al*. [8] estimated daily global solar radiation over large areas using artificial neural network. The model uses clear-sky estimates and satellite images as input variables. Noorian *et al*. [9] evaluated the performance of 12 different models to appraise the hourly diffuse solar radiation on tilted surfaces from data on horizontal surfaces. Twelve models were tested against recorded irradiation on south- and west-facing surfaces at Karaj (35°55' N; 50°56' E), Iran.

Furlan *et al*. [10] estimated a new regression model developed to estimate the hourly values of diffuse solar radiation at the surface. The model is based on the clearness index and diffuse fraction relationship and includes the effects of cloud (cloudiness and cloud type), traditional meteorological variables (air temperature, relative humidity and atmospheric pressure observed at the surface) and air pollution (concentration of particulate matter observed at the surface).Many authors have presented empirical correlations to estimate the monthly average daily radiation on a horizontal surface [11-18].

In this study, the amount of monthly and yearly averageof daily solar radiation incident for the provinces and main cities of Egyptas the amount of output energy from photovoltaicpanels fixed on selected geometries in various tilted directionshas been determined using Matlab/GUI Interface [3] and the measuredradiation data on a horizontal surface at Egypt.

The proposed methodology starts from irradiation data, combining diffuse model and daily–hourly relations. The solar radiation received from the Sun without having been scattered by the atmosphere is called the beam solar component (beam radiation is often referred to as direct solar radiation; to avoid confusion between subscripts for direct and diffuse; we use the term beam radiation). But the solar radiation received from the Sun after its direction has been changed by scattering by the atmosphere is called the diffuse solar component. Global solar radiation is the algebraic sum of three solar components; first is the direct (beam) solar radiation, the second is the diffuse solar radiation and the third is the ground reflected solar radiation.

Equations Models for Extraterrestrial Solar Radiation Calculations: Throughout the year, the extraterrestrial radiation measured on the plane normal to the radiation on the N[th] day of the year, G_{Bn}, can be calculated by [19, 20]:

$$G_{Bn} = G_{sc}\left[1+0.033\cos\left(\frac{360N}{365}\right)\right] \tag{1}$$

The latest value of the solar constant $G_{sc}$is 1366.1 W/m^2.

When a surface is placed parallel to the ground, the rate of solar radiation (G_B) incident on this extraterrestrial horizontal surface at a given time of the year is given by:

$$G_B = G_{Bn}\times\begin{bmatrix}\sin(L)\sin(\delta)\\ +\cos(L)\cos(\delta)\cos(h)\end{bmatrix} \tag{2}$$

where the local latitude L, the declination δ and the solar hour angleh are presented in Eq. (2).

Total Solar Radiation on Tilted Surfaces: Usually, solar collectors are not installed horizontally but at an angle to increase the amount of solar radiation intercepted and reduce reflection and losses. Therefore, system designers need data about solar radiation on such titled surfaces. Therefore, there is a need to convert these data to solar radiation on tilted surfaces. The amount of insolation on a surface at a given location for a given time depends on the orientation and slope of the surface.

A flat surface absorbs beam (G_{Bt}), diffuse (G_{Dt}) and ground-reflected (G_{Rt}) solar radiation; that is [21, 22],

$$G_t = G_{bt} + G_{dt} + G_{Rt} \tag{3}$$

Beam Radiation: The beam component is calculated using the direct normal irradiance (G_{Bn}) from the simulation model.

As shown in Fig. 1, the beam radiation on a tilted surface is.

$$G_{bt} = G_{ba}\cos(\theta) \tag{4}$$

and on a horizontal surface.

$$G_B = G_{Ba}\cos(\Phi) \tag{5}$$

It follows that

$$R_B = \frac{G_{B_t}}{G_B} = \frac{\cos(\theta)}{\cos(\Phi)} \tag{6}$$

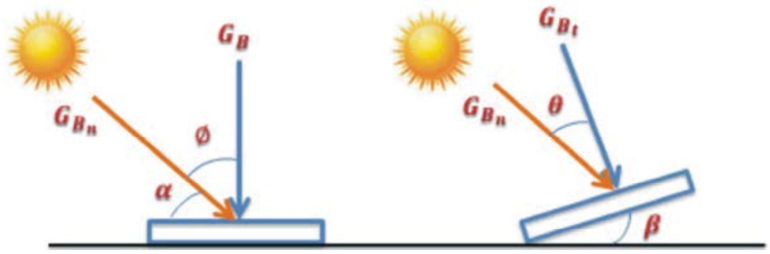


Fig. 1: Beam radiations on horizontal and tilted surfaces

where R_B is the beam radiation tilt factor.

The beam radiation component for any surface is

$$G_{bt} = G_B R_B \tag{7}$$

In Eq. (6), the zenith angle (Φ) and the incident angle (θ) can be Simplified. Therefore, Eq. (6) becomes.

$$R_B = \frac{\cos(\theta)}{\cos(\Phi)} = \frac{\sin(L-\beta)\sin(\delta)+\cos(L-\beta)\cos(\delta)\cos(h)}{\sin(L)\sin(\delta)+\cos(L)\cos(\delta)\cos(h)} \tag{8}$$

where β is the angle of the tilted surface.

Diffuse Radiation: The diffuse radiation on a tilted surface is:

$$G_{dt} = G_D R_D \tag{9}$$

$$G_{dt} = (0.11xG_{Ba})\, R_D \tag{10}$$

The ground reflected radiation, on a tilted surface is calculatedby Isotropic model of Liu and Jordan [5, 23, 24].

In this model, the calculations of R_D is simple and given by.

$$R_D = \frac{1+\cos(\beta)}{2} \tag{11}$$

R_D is is called the tilt factor for diffuse radiation.

Ground Reflected Radiation: The ground reflected radiation on a tilted surface is:

$$G_{rt} = (G_B + G_D)\, R_E \tag{12}$$

$$R_R = \rho\left[\frac{1-\cos(\beta)}{2}\right] \tag{13}$$

where R_R is called the tilt factor for ground reflected radiation and ρ is the ground reflectance.

The solar radiation simulation model willbe showed and results will be presented and discussed in results section.

RESULTS

The present study was carried out for the provinces and main cities of Egypt. Also, this study was specified results for the six main provinces and cities of Egypt" Alexandria, El Giza, Aswan, Sinai, Asyut, Marsa Matruh". The above formulaswere used to calculate the average daily total radiation on a south-facing surface as the tilt angle 30° and on a horizontal surface. The solar radiations were calculated as three parts (direct, diffuse and ground reflected) radiation. The data of site such as (Latitude and Longitude) [26] will be inserted as specified in Tables (2, 3, 4 and 5). The optimum place and the construction for tilted and horizontal surfaceswere calculated by searching for the values of which the daily total solar radiation was at a maximum for a specific period. Therefore, the optimum placewas found for certain provinces and sites in Egypt.

In this study uses a basic equations method and simulate it using Matlabto make appropriate site selections in order to achieve sustainable development by effective solar radiation site. Solar radiation data was simulated by MATLAB®/GUI interface software [3, 25] and the results will be discussed. The simulation selecting the best site with best solar radiation data for photovoltaic power plants or solar thermalpower plants to have an optimize system according to solar radiation data for sites.Information for the provinces and sites considered in this study is givenin Fig. 2 and Table 1.

The results analysis will be discussed as follow:

- Determination of hourly solar radiation on inclined surface during one day.
- Determination of daily solar radiation on horizontal surface during year months.
- Determination of daily solar radiation on an inclined surface during year months.

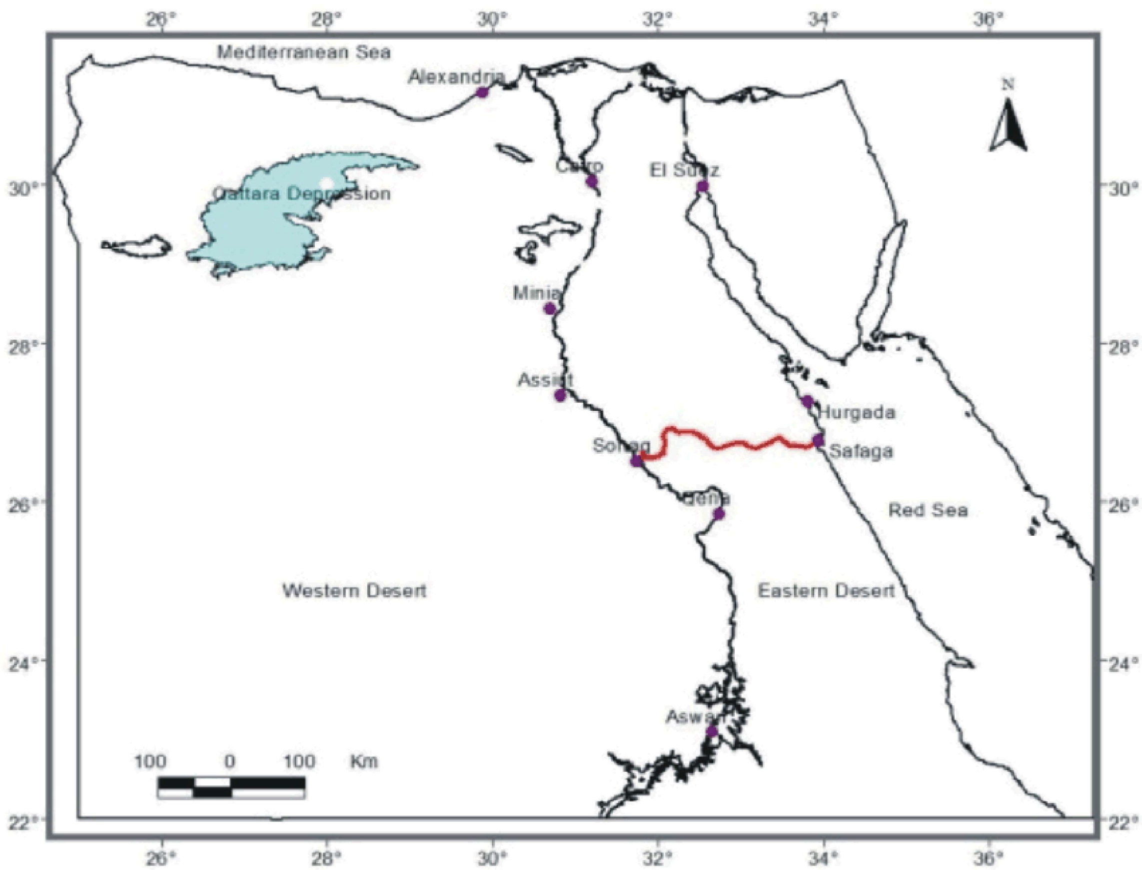


Fig. 2: Latitude and longitude data map for Egypt [26]

Table 1: Information for the province "Giza" considered in the study for solar radiation calculations

Location	Egypt - Giza National Research Centre
The standard meridian, Egypt	31° 17' East
The local longitude, Giza	31° 10' East
The local latitude, Giza	30° 00' North
Date	Changes over the year
Time	Changes over the day
The ground reflectance	0.27
Tilt angle, **	30

Determination of hourly solar radiation on inclined surface.

- Input data for place site (Giza) as latitude and longitude are showed in Table 1 [26] for Matlab simulation model. Fig. 3 shows the amount of daily solar insolation during the daytime using solar pyranometer. It is shown in Fig. 3 that the maximum solar radiation applied in an inclined plane (South facing -Tilted 30°) is 920 W/m^2 and 900W/m^2 for a horizontal plane at 12:00 PM.
- The results in Fig. 4 show estimation of daily solar radiation on an inclined plane (South facing -Tilted 30°) during day hours at main provinces and cities in Egypt "Alexandria, El Giza,Aswan, Sinai, Asyut, Marsa Matruh" using Matlab/GUI. It is shown in Fig. 4 that the maximum solar radiation applied in plane is 1012 W/m^2 at 12:00 PM for El Giza city. The results of daily solar radiation during daytime are showed using Matlab/GUI software.
- Fig. 5 shows Matlab/GUI estimation of Daily Solar Radiation on an inclined plane (South facing -Tilted 30°) during day hours on 2 March at Giza. Fig. 5 presents the simulation results obtained that the solar radiation reached the maximal value of 1012 W/m^2 in 12:00 A.M.
- Table 2 shows the simulation results of the hourly solar radiation data in three component parts (Direct, Diffuse and reflected) radiation and total daily solar radiation on an inclined plane (South facing -Tilted 30°) on 2 March for the six provinces of Egypt. Thehourly solar radiation on an inclined plane (South facing -Tilted 30°) to be used in 2 March for each province and city of Egypt are showed in Table 3.

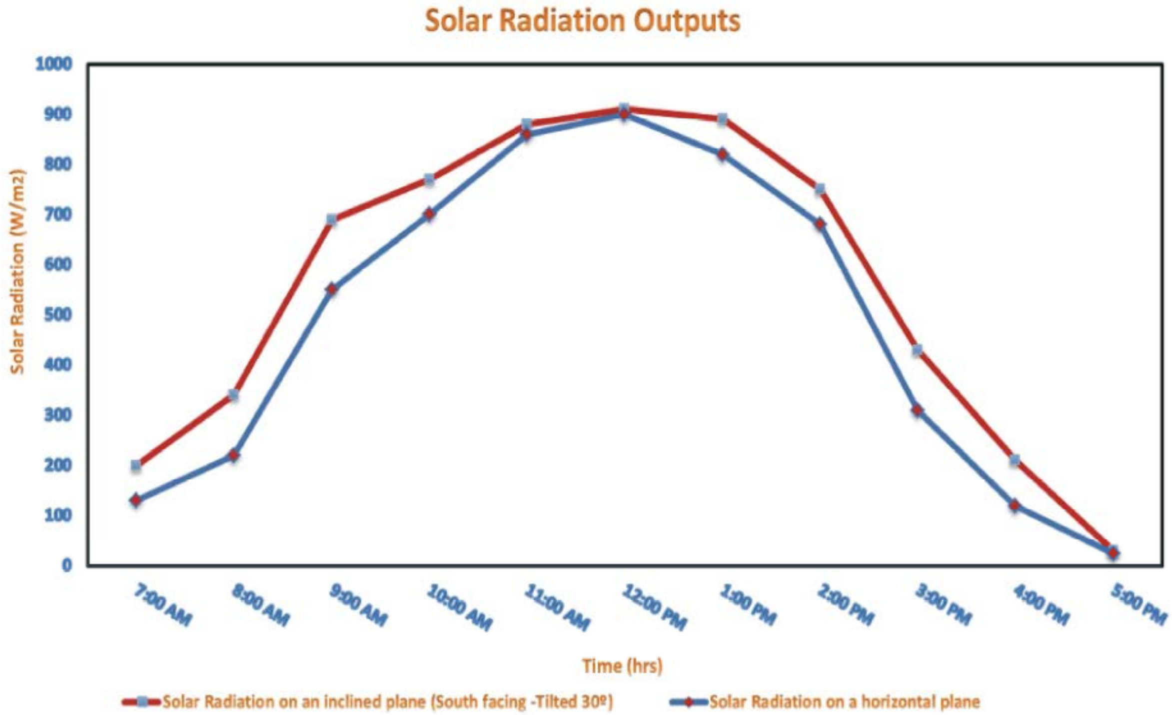


Fig. 3: Practical Solar Radiation onan inclined plane (South facing -Tilted 30°) and a horizontal plane during day hours on 2 March in Giza

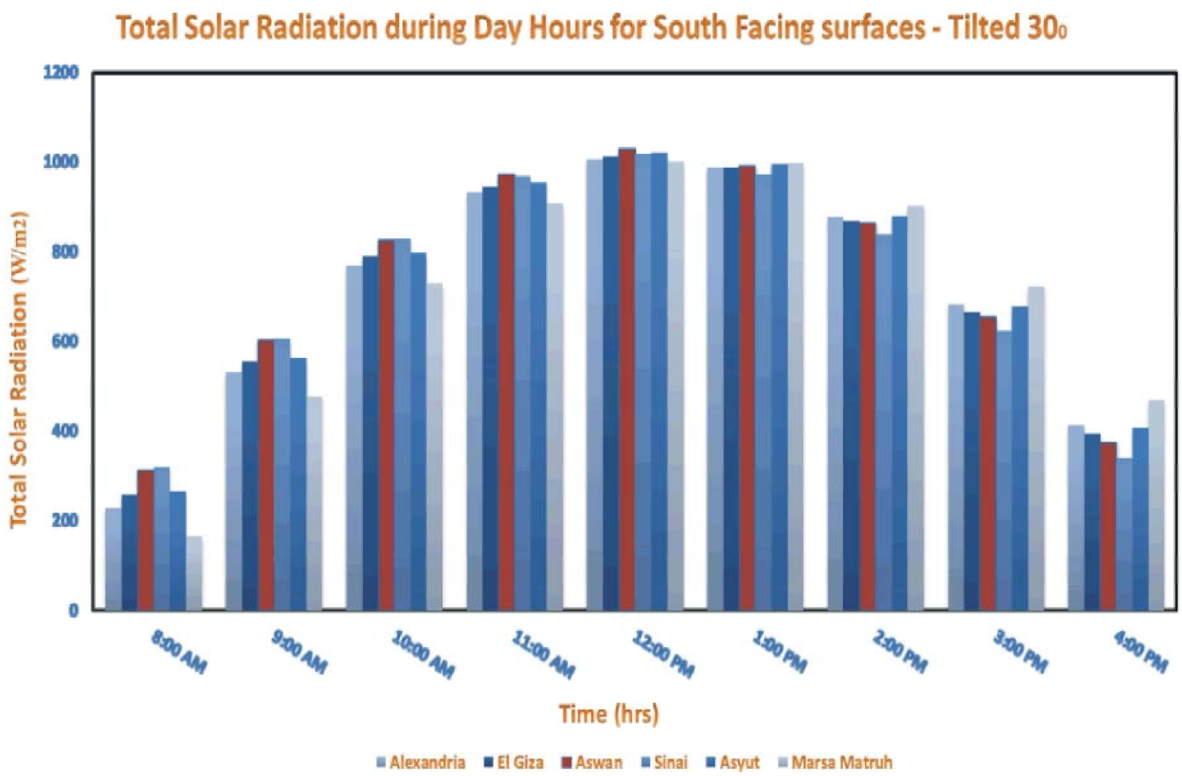
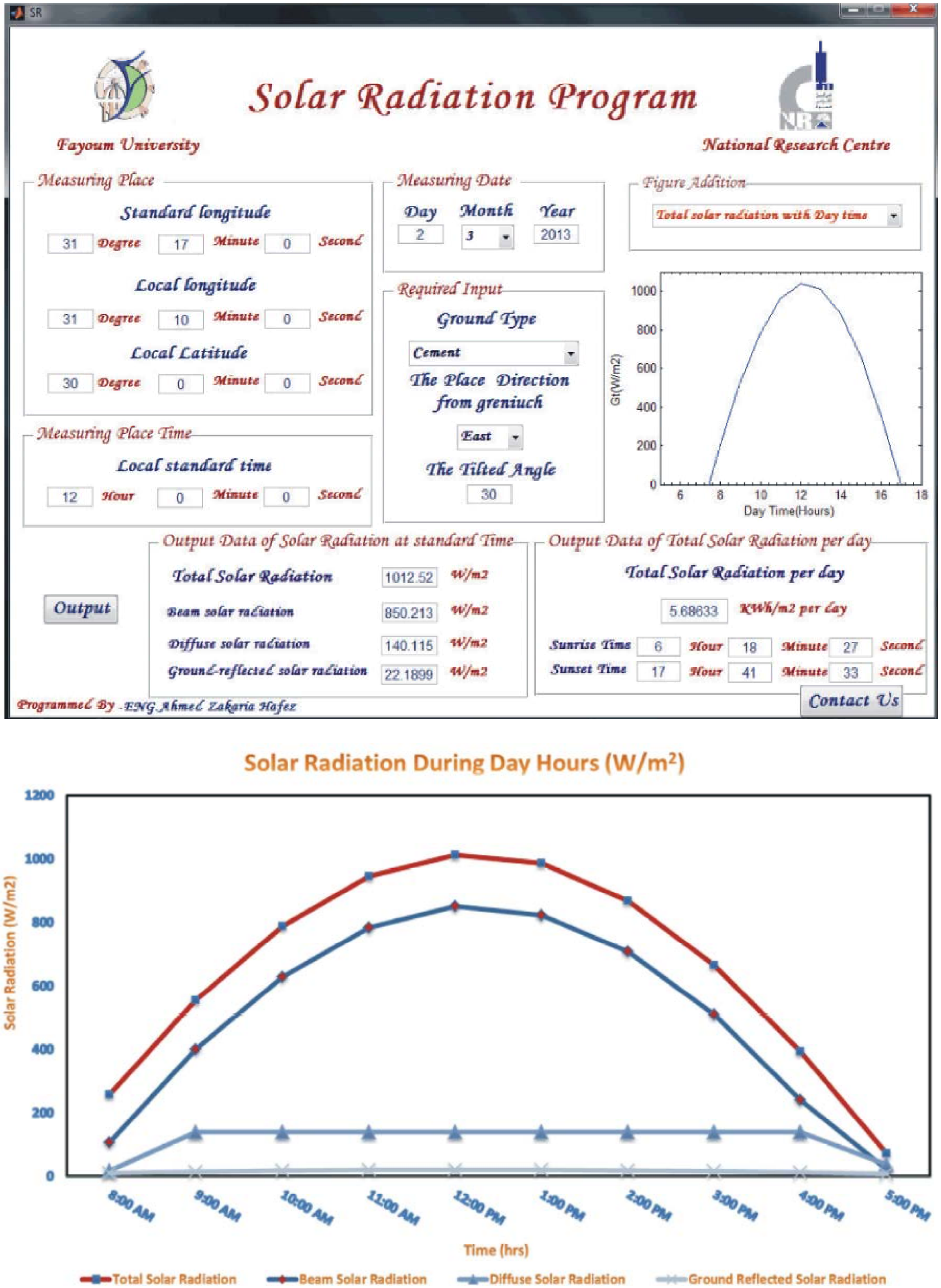


Fig. 4: Estimation of Daily Solar Radiation on an inclined plane (South facing -Tilted 30°) during Day Hours on 2 March using Matlab/GUI



(a)

(b)

Fig. 5: Estimation of Daily Solar Radiation on an inclined plane (South facing -Tilted 30°) during Day Hours in Giza on 2 March (a) Matlab GUI/Interface simulation model (b) Solar Radiation Data during Day Hours

Table 2: Direct, Diffuse, Reflected and Global Daily Solar Radiation data during day hours in 2 Marchon an inclined plane (South facing -Tilted 30°) at Egypt

Locations	Latitude	Longitude	Solar Radiation	Day Hours 6	7	8	9	10	11	12	13	14	15	16	17	18	Daily Solar Radiation (Kwh/m^2/day)
Aswan	24°04' N	32°57' E	Beam			160	445	665	809	864	828	702	495	222			5.97709
			Diffuse			140	140	140	140	140	140	140	140	140			
			Reflected			12	17	20	23	24	23	21	18	13			
			Total			312	602	826	972	1028	991	863	653	375			
Asyut	27°11' N	31°04' E	Beam			114	406	637	792	859	833	718	520	253			5.80288
			Diffuse			140	140	140	140	140	140	140	140	140			
			Reflected			11	15	19	21	22	22	20	17	13			
			Total			265	561	796	953	1021	995	878	677	406			
El Giza	30°00' N	31°10' E	Beam			107	400	630	784	850	824	708	510	242			5.68633
			Diffuse			140	140	140	140	140	140	140	140	140			
			Reflected			11	15	19	21	22	22	20	16	13			
			Total			258	555	789	945	1012	986	868	666	395			
Sinai Peninsula	29°30' N	34°0' E	Beam			168	450	667	805	854	811	678	466	187			5.81451
			Diffuse			140	140	140	140	140	140	140	140	140			
			Reflected			11	16	20	22	22	22	20	16	12			
			Total			319	606	827	967	1016	973	838	622	339			
Alexandria	31°13' N	29°58' E	Beam			78	374	610	770	844	826	716	524	261			5.57169
			Diffuse			140	140	140	140	140	140	140	140	140			
			Reflected			10	15	19	21	22	21	20	17	13			
			Total			228	529	769	931	1006	987	876	681	414			
MarsaMatruh	31°19' N	27°09' E	Beam			16	318	568	744	835	833	742	566	316			5.41816
			Diffuse			140	140	140	140	140	140	140	140	140			
			Reflected			10	18	21	23	24	24	21	17	13			
			Total			166	476	729	907	999	997	903	723	469			

Table 3: Solar radiation Data during day hours in 2 March on an inclined plane (South facing -Tilted 30°) at Egypt

Locations	Latitude	Longitude	Solar Radiation During Day Hours (W/m^2) 6	7	8	9	10	11	12	13	14	15	16	17	18	Daily Solar Radiation (Kwh/m^2/day)
Alexandria	31°13' N	29°58' E			228	529	769	931	1005	987	876	681	414	95		5.57169
Aswan	24°04' N	32°57' E			312	602	826	972	1028	991	863	653	375	49		5.97709
Asyut	27°11' N	31°04' E			265	561	796	953	1021	995	878	677	406	83		5.80288
BeniSuef	29°05' N	31°06' E			259	556	791	948	1015	990	872	671	399	76		5.72582
Bur Said	31°16' N	32°18' E			228	570	799	949	1009	976	851	644	367	42		5.66893
Cairo	30°01' N	31°14' E			259	556	790	946	1013	986	867	665	393	70		5.68836
Damanhur	31°00' N	30°30' E			240	539	777	936	1008	986	872	673	405	83		5.60756
Dumyat	31°24' N	31°48' E			266	561	792	945	1008	978	856	651	377	52		5.64233
El Arish	31°08' N	33°50' E			310	597	819	960	1010	968	834	619	337			5.72992
El Faiyum	29°19' N	30°50' E			253	551	787	945	1014	990	874	674	404	82		5.7038
El Giza	30°00' N	31°10' E			258	555	789	945	1012	986	868	666	395	72		5.68633
El Mahalla El Kubra	31°00' N	31°00' E			251	548	783	940	1009	983	866	666	395	72		5.62968
El Mansura	31°00' N	31°19' E			258	554	787	943	1009	982	863	660	388	65		5.64319
El Minya	28°07' N	30°33' E			251	550	787	946	1017	995	881	682	413	92		5.74335
El Suweis	29°58' N	32°31' E			287	579	807	955	1014	979	853	645	368	41		5.74178
Helwan	29°50' N	31°20' E			262	558	792	947	1013	986	867	664	392	69		5.70127
Hurghada	27°15' N	33°50' E			323	610	831	972	1023	980	846	631	349	19		5.90326
Ismailiya	30°37' N	32°18' E			280	573	802	951	1012	978	854	646	370	44		5.702
Luxor	25°41' N	32°38' E			302	593	820	967	1025	990	864	655	378	52		5.9176
MarsaMatruh	31°19' N	27°09' E			166	476	729	907	999	997	903	723	469	158		5.41816
Qena	26°10' N	32°43' E			302	593	820	967	1025	989	862	652	375	48		5.90444
Sinai Peninsula	29°30' N	34°0' E			319	606	827	967	1016	973	838	622	339			5.81451
Sohag	26°33' N	31°43' E			280	575	806	959	1023	993	872	668	394	70		5.85303
Zagazig	30°40' N	31°30' E			263	558	791	945	1011	982	862	659	386	62		5.66771

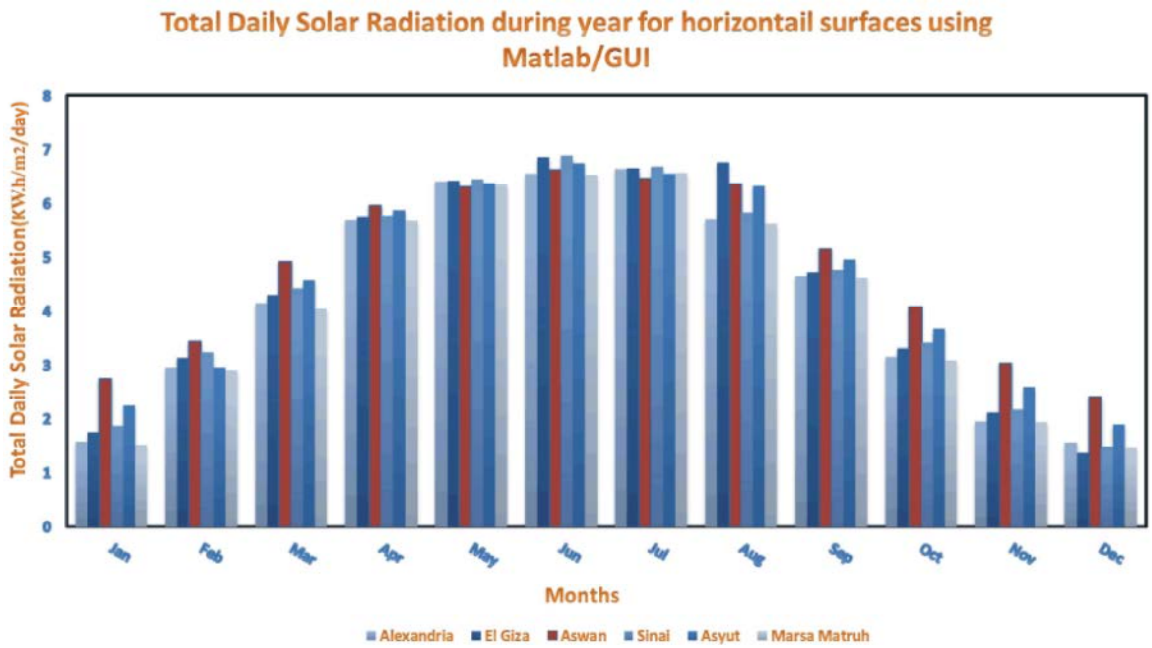


Fig. 6: Estimation of Daily Solar Radiation on a horizontal plane during year months forsix governancesusing Matlab/GUI

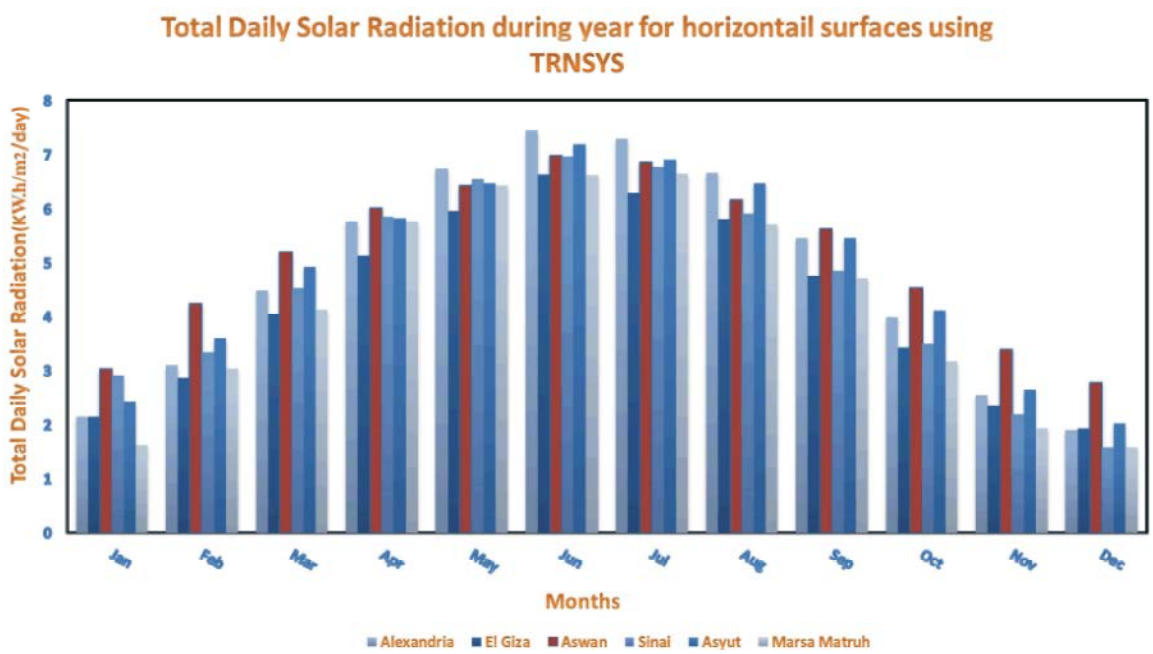


Fig. 7: Estimation of Daily Solar Radiation on a horizontal plane during year months forsix governancesusing TRNSYS

Determination of Daily Solar Radiation on Horizontal Surface:

- The average daily solar radiation of horizontal surfaces during year months for the six provinces and cities" Alexandria, El Giza, Aswan, Sinai, Asyut, MarsaMatruh"of Egypt are presented in Fig. 6 using Matlab/GUI software and in Fig. 7 using TRNSYS Program. In general, the daily values of solar global radiation/insolation using Matlab/GUI Interface (of the locations considered in the study) range from 1.5-6.9 kWh/m^2/day and using TRNSYS program from 1.6-7.45 kWh/m^2/day.

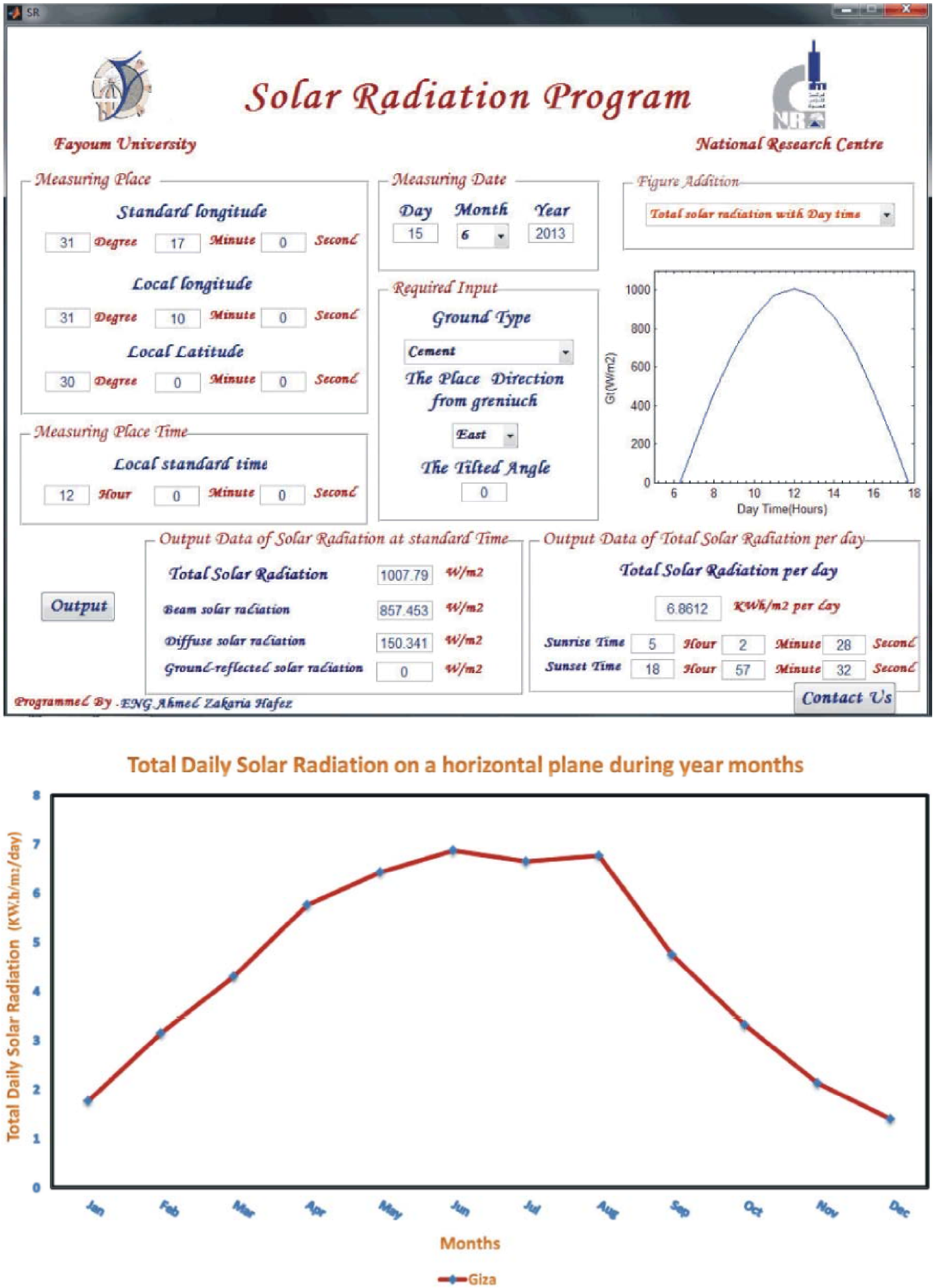
Table 4(a): Estimation of Daily Solar Radiation on a horizontal plane during year months at Egypt

			Daily Solar Radiation on a Horizontal plane(Kwh/m^2/day)											
Locations	Latitude	Longitude	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alexandria	31°13' N	29°58' E	1.57664	2.97015	4.15307	5.7067	6.40792	6.55293	6.64676	5.71448	4.65099	3.15562	1.96089	1.55986
Aswan	24°04' N	32°57' E	2.75289	3.44326	4.91751	5.97457	6.32412	6.62636	6.47614	6.36482	5.16626	4.08701	3.04233	2.40697
Asyut	27°11' N	31°04' E	2.25119	2.96894	4.58668	5.88083	6.37458	6.74867	6.56107	6.33178	4.96511	3.69241	2.59253	1.90026
BeniSuef	29°05' N	31°06' E	1.94102	3.28249	4.40363	5.80636	6.40722	6.82706	6.62159	5.77715	4.82227	3.45111	2.29447	1.57692
Bur Said	31°16' N	32°18' E	1.58177	2.98581	4.21137	5.70554	6.4469	6.55583	6.69958	5.76616	4.64037	3.17422	1.93114	1.58786
Cairo	30°01' N	31°14' E	1.78697	3.15397	4.31343	5.76565	6.42064	6.86301	6.64929	5.76654	4.74797	3.33075	2.14445	1.41555
Damanhur	31°00' N	30°30' E	1.61746	3.00746	4.19151	5.7188	6.41649	6.88082	6.65519	5.73197	4.66893	3.19173	1.99233	1.60484
Dumyat	31°24' N	31°48' E	1.55749	2.96307	4.18494	5.69991	6.44051	6.5621	6.69227	5.75328	4.63175	3.15207	1.91527	1.55925
El Arish	31°08' N	33°50' E	1.60572	3.01203	4.25923	5.70499	6.46417	6.54407	6.72374	5.796	4.63931	3.20083	1.93099	1.62647
El Faiyum	29°19' N	30°50' E	1.90076	3.24743	4.37285	5.79615	6.40568	6.83058	6.62191	5.76775	4.80465	3.41778	2.25983	1.53741
El Giza	30°00' N	31°10' E	1.76435	3.13462	4.29801	5.75957	6.42089	6.8663	6.65108	6.76284	4.73741	3.31246	2.1237	1.39262
El Mahalla El Kubra	31°00' N	31°00' E	1.62086	3.01286	4.20568	5.71959	6.42527	6.89054	6.66678	5.74377	4.66807	3.19768	1.98817	1.61308
El Mansura	31°00' N	31°19' E	1.62268	3.01594	4.2143	5.71974	6.43052	6.89638	6.67381	5.75092	4.66717	3.20111	1.98521	1.61799
El Minya	28°07' N	30°33' E	2.09601	2.82294	4.48252	5.84491	6.38263	6.77821	6.57975	6.31403	4.89729	3.56851	2.45163	1.74322
El Suweis	29°58' N	32°31' E	1.80043	3.17114	4.35135	5.76605	6.43928	6.883	6.67457	5.79426	4.74581	3.34885	2.13794	1.41837
Helwan	29°50' N	31°20' E	1.81805	3.18057	4.33478	5.77389	6.42033	6.85852	6.6469	5.7717	4.76237	3.3559	2.17281	1.44698
Hurghada	27°15' N	33°50' E	2.2476	3.03493	4.64857	5.8699	6.41421	6.79566	6.61805	6.33116	4.94214	3.70513	2.54589	1.87201
Ismailiya	30°37' N	32°18' E	1.69117	3.07822	4.27929	5.73677	6.44235	6.90106	6.68573	5.77877	4.69436	3.2612	2.0363	1.30677
Luxor	25°41' N	32°38' E	2.49812	3.21929	4.76692	5.9293	6.36495	6.7059	6.53877	6.35328	5.06269	3.89182	2.80428	2.1437
MarsaMatruh	31°19' N	27°09' E	1.5252	2.9094	4.04661	5.68095	6.34401	6.53921	6.5689	5.63071	4.63078	3.09226	1.95223	1.48239
Qena	26°10' N	32°43' E	2.4213	3.15596	4.72482	5.91344	6.37779	6.73064	6.55917	6.34802	5.02889	3.83345	2.72956	2.06281
Sinai Peninsula	29°30' N	34°0' E	1.87872	3.24261	4.43118	5.77898	6.45115	6.88687	6.68839	5.82747	4.77017	3.41779	2.19024	1.48702
Sohag	26°33' N	31°43' E	2.35668	3.07559	4.66392	5.90302	6.37197	6.73205	6.55301	6.34256	5.00803	3.77796	2.68347	2.00439
Zagazig	30°40' N	31°30' E	1.67966	3.0649	4.25384	5.73561	6.43094	6.88926	6.67047	5.76124	4.69413	3.24747	2.03727	1.30173

Table 4(b): Estimation of Daily Solar Radiation on a horizontal plane during year months at Egypt using TRNSYS

			Daily Solar Radiation on a Horizontal plane(Kwh/m^2/day)											
Locations	Latitude	Longitude	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alexandria	31°13' N	29°58' E	2.16	3.11	4.5	5.77	6.75	7.45	7.31	6.68	5.46	4.00	2.55	1.92
Aswan	24°04' N	32°57' E	3.04	4.25	5.20	6.03	6.44	7.00	6.86	6.18	5.63	4.54	3.40	2.78
Asyut	27°11' N	31°04' E	2.44	3.61	4.94	5.83	6.48	7.20	6.92	6.48	5.47	4.13	2.65	2.04
BeniSuef	29°05' N	31°06' E	2.27	3.20	4.40	5.69	6.56	7.19	7.00	6.37	5.05	3.69	2.44	1.97
Bur Said	31°16' N	32°18' E	2.18	3.05	4.40	5.64	6.74	7.39	7.06	6.50	5.43	3.98	2.59	1.92
Cairo	30°01' N	31°14' E	2.16	2.88	4.05	5.14	5.96	6.65	6.30	5.82	4.77	3.44	2.36	1.95
Damanhur	31°00' N	30°30' E	1.98	2.91	4.26	5.47	6.53	7.32	7.09	6.44	5.29	3.90	2.46	1.75
Dumyat	31°24' N	31°48' E	1.65	3.06	4.28	5.79	6.54	6.66	6.79	5.85	4.73	3.25	2.01	1.65
El Arish	31°08' N	33°50' E	2.14	3.04	4.36	5.53	6.62	7.24	6.85	6.34	5.27	3.90	2.56	1.91
El Faiyum	29°19' N	30°50' E	2.23	3.27	4.53	5.68	6.62	7.36	7.08	6.46	5.29	3.76	2.48	1.97
El Giza	30°00' N	31°10' E	2.16	2.88	4.05	5.14	5.96	6.65	6.30	5.82	4.77	3.44	2.36	1.95
El Mahalla El Kubra	31°00' N	31°00' E	1.98	2.81	4.08	5.35	6.41	7.06	6.74	6.16	5.10	3.62	2.34	1.70
El Mansura	31°00' N	31°19' E	1.98	2.81	4.08	5.35	6.41	7.06	6.74	6.16	5.10	3.62	2.34	1.70
El Minya	28°07' N	30°33' E	2.43	3.53	4.72	5.69	6.57	7.27	6.94	6.40	5.36	4.05	2.72	2.14
El Suweis	29°58' N	32°31' E	2.00	2.89	4.15	5.31	6.32	6.96	6.72	5.99	4.94	3.44	2.23	1.78
Helwan	29°50' N	31°20' E	2.28	3.20	4.40	5.68	6.56	7.19	7.00	6.37	5.05	3.69	2.44	1.98
Hurghada	27°15' N	33°50' E	2.34	3.13	4.72	5.96	6.51	6.89	6.71	6.43	4.04	3.80	2.64	1.97
Ismailiya	30°37' N	32°18' E	2.01	2.89	4.15	5.31	6.32	6.96	6.72	5.99	4.94	3.44	2.23	1.78
Luxor	25°41' N	32°38' E	2.77	4.03	5.20	5.89	6.28	6.99	6.80	6.34	5.51	4.29	3.20	2.57
MarsaMatruh	31°19' N	27°09' E	1.62	3.05	4.14	5.78	6.44	6.63	6.66	5.72	4.73	3.19	1.95	1.58
Qena	26°10' N	32°43' E	2.77	3.79	4.89	5.73	6.17	6.98	6.72	6.27	5.25	4.03	2.86	2.39
Sinai Peninsula	29°30' N	34°0' E	2.92	3.34	4.54	5.87	6.55	6.98	6.78	5.92	4.87	3.51	2.20	1.58
Sohag	26°33' N	31°43' E	2.75	3.98	5.08	5.80	6.34	7.09	6.88	6.46	5.64	4.47	3.11	2.49
Zagazig	30°40' N	31°30' E	2.16	2.88	4.05	5.14	5.96	6.65	6.29	5.82	4.77	3.44	2.37	1.95

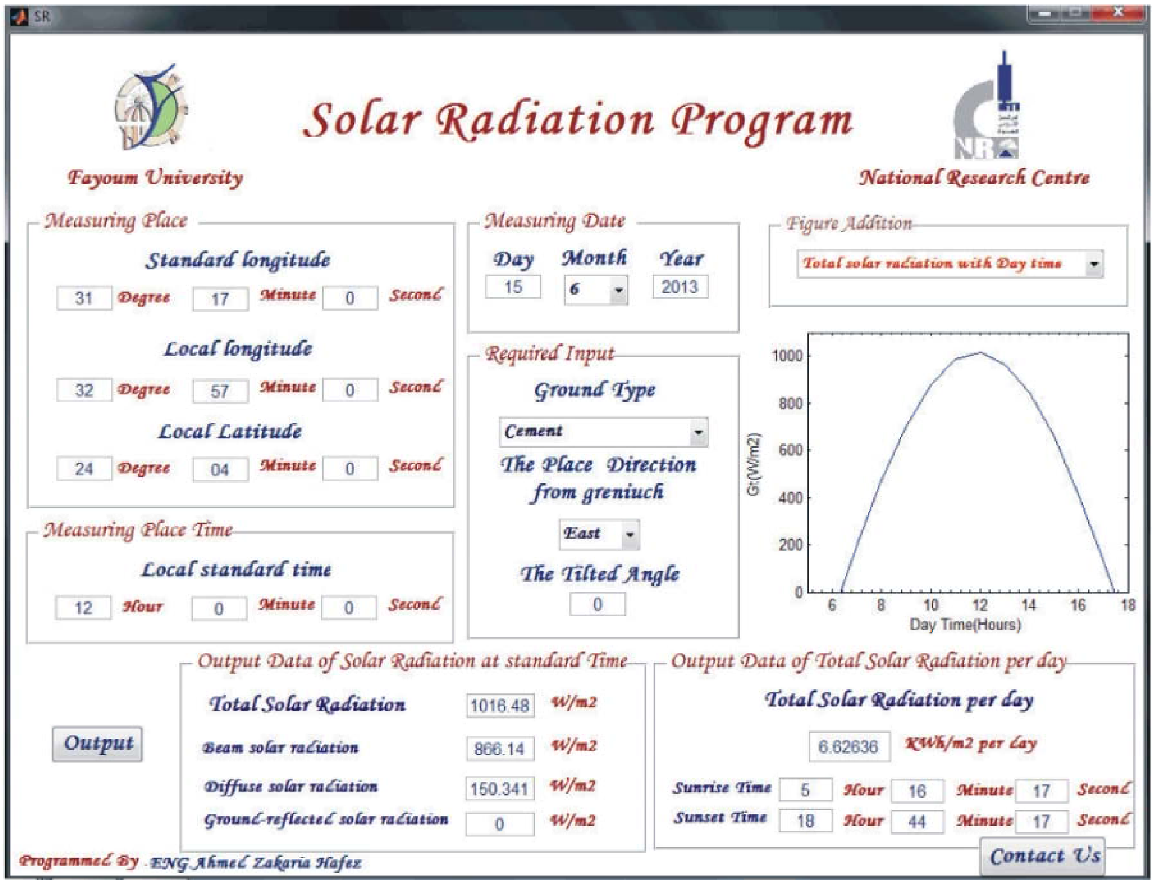
- Tables 4 shows the daily solar radiation on a horizontalplaneto be used in winter (December, January and February), in spring (March, April and May), in summer (June, July and August) and in autumn (September, October and November) for each province and city in Egypt. It can be depicted from Tables 4, Fig. 6 and Fig. 7 that solar radiation is generally higher during the summer months (May to August) as compared to other months (this is due to topography). This implies that solar systems would produce appreciably more energy during summer time. This seasonal pattern/trend of solar radiation matches with the higher load requirements during summer period in Egypt. This is a favorablecharacteristic because electricity demand is high during the summer months in Egypt Relatively less load can be met/covered during non-summer months because of blocking of sun's rays by clouds.



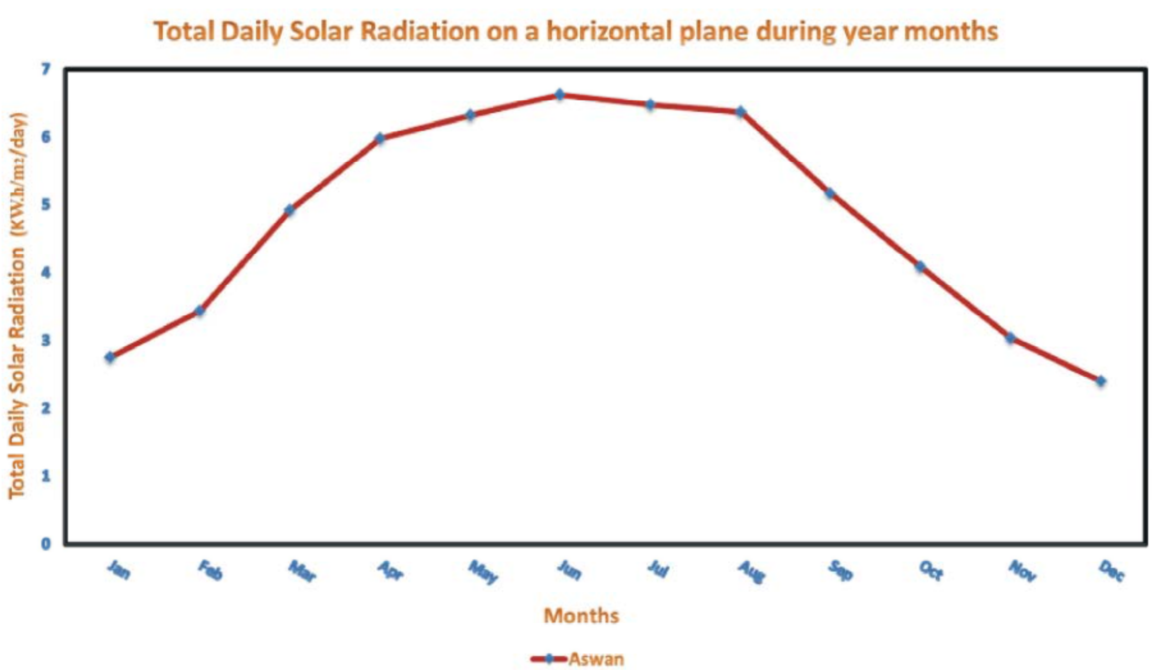
(a)

(b)

Fig. 8: Estimation of Daily Solar Radiation on a horizontal plane during year months at Giza
(a) Matlab GUI/Interface simulation model (b) Solar Radiation Data during year months



(a)



(b)

Fig. 9: Estimation of Daily Solar Radiation on a horizontal plane during year months at Aswan
(a) Matlab GUI/Interface simulation model (b) Solar Radiation Data during year months

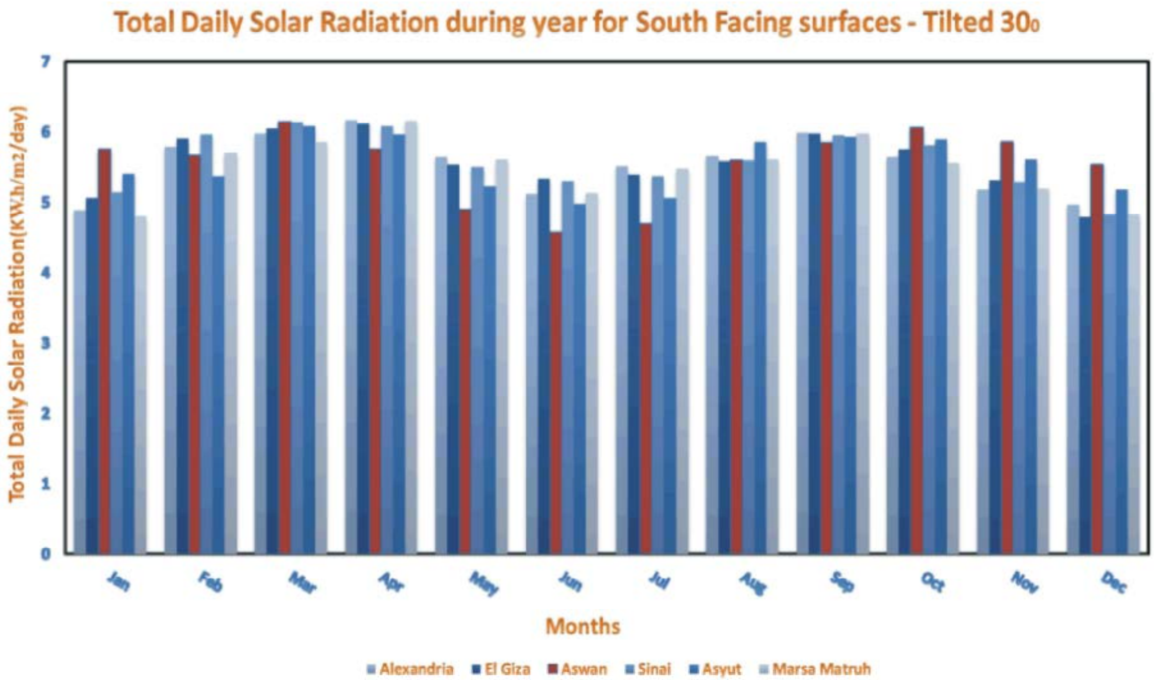
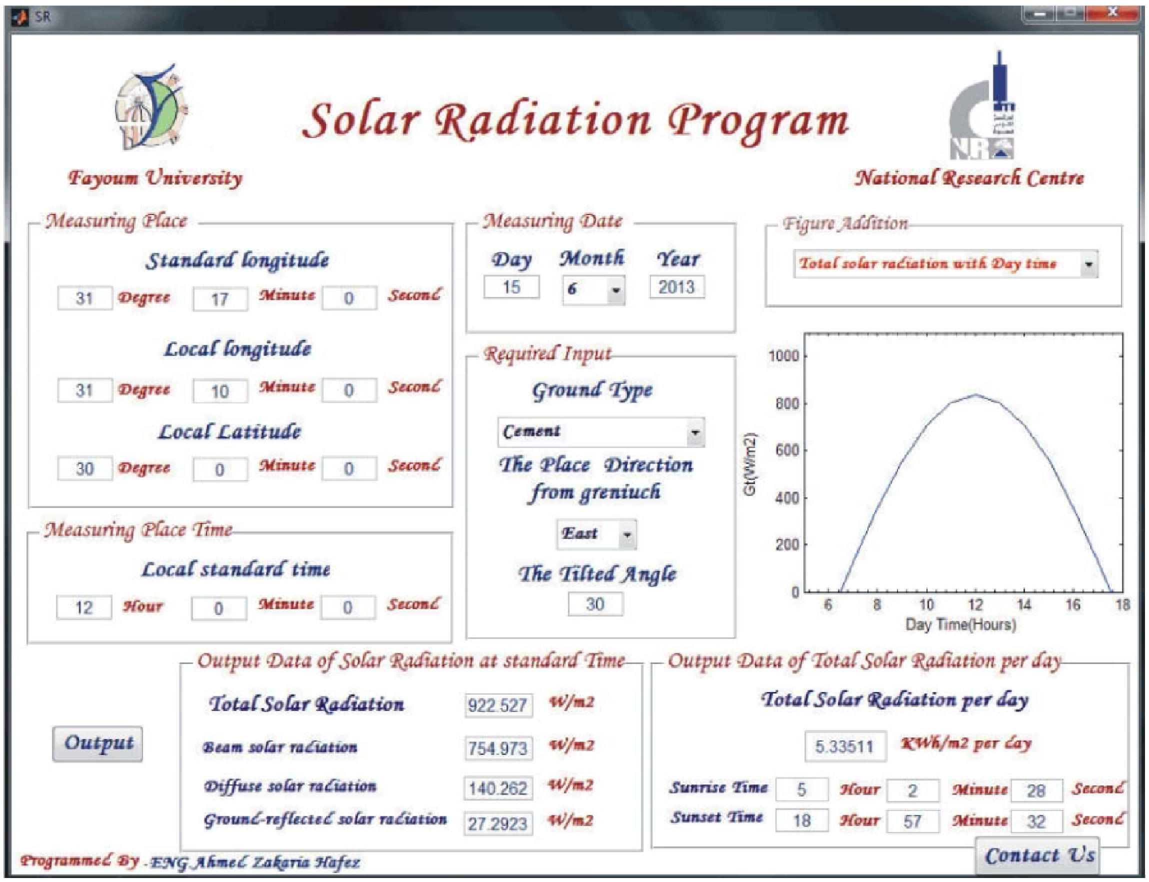


Fig. 10: Estimation of Daily Solar Radiation on an inclined plane (South facing -Tilted 30°) during year months for six governances

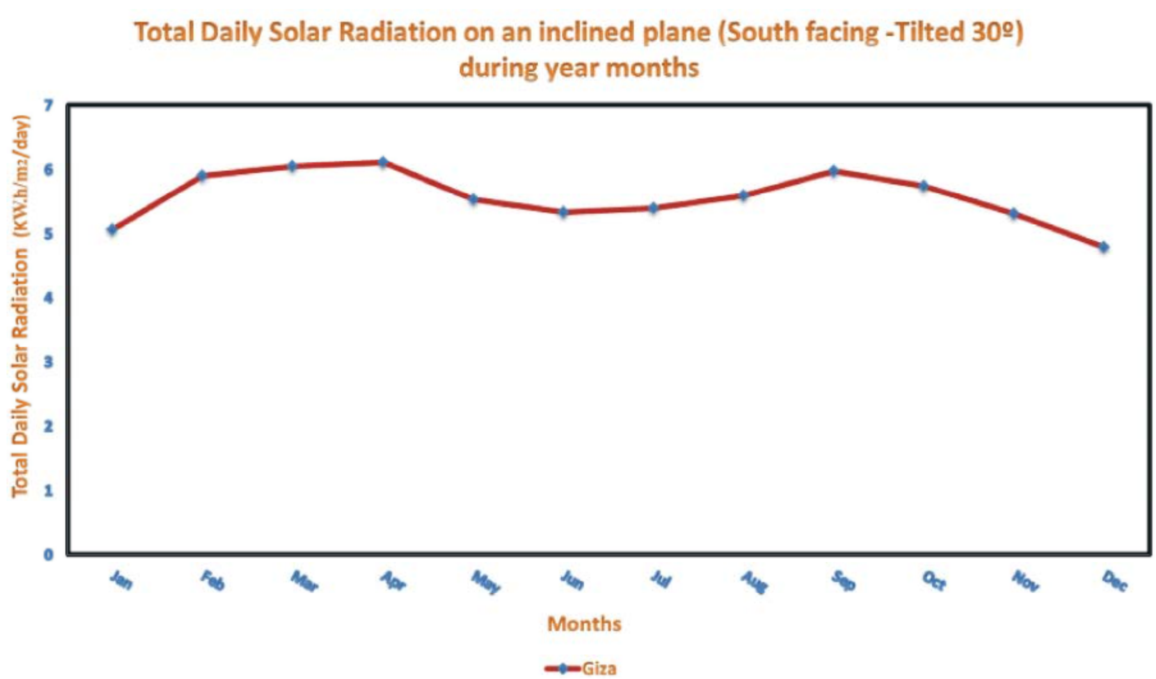
Table 5: Estimation of Daily Solar Radiation on an inclined plane (South facing -Tilted 30°) during year months at Egypt

			Daily Solar Radiation on an inclined plane (South facing -Tilted 30°) (Kwh/m^2/day)											
Locations	Latitude	Longitude	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alexandria	31°13' N	29°58' E	4.88615	5.78982	5.98328	6.17179	5.64099	5.12774	5.52021	5.66051	5.98751	5.64986	5.18765	4.97099
Aswan	24°04' N	32°57' E	5.75373	5.67246	6.14965	5.75803	4.89425	4.57493	4.69509	5.59775	5.84485	6.0561	5.86044	5.54269
Asyut	27°11' N	31°04' E	5.40582	5.37477	6.08178	5.96019	5.2325	4.97646	5.06532	5.86025	5.93237	5.89726	5.60997	5.17957
BeniSuef	29°05' N	31°06' E	5.18008	5.96705	6.06222	6.06715	5.43712	5.22025	5.29308	5.51807	5.96404	5.79873	5.41139	4.92115
Bur Said	31°16' N	32°18' E	4.90947	5.82412	6.06333	6.1753	5.67173	5.13451	5.55805	5.7051	5.98069	5.68631	5.1374	5.04426
Cairo	30°01' N	31°14' E	5.0641	5.90312	6.05237	6.11569	5.53531	5.53531	5.4031	5.59361	5.97503	5.74752	5.3057	4.78597
Damanhur	31°00' N	30°30' E	4.92479	5.81724	6.00791	6.16302	5.62618	5.44955	5.50413	5.65479	5.98574	5.67456	5.20551	5.01961
Dumyat	31°24' N	31°48' E	4.88754	5.80765	6.04468	6.18235	5.68012	5.1518	5.56666	5.70702	5.98448	5.67125	5.13341	5.01237
El Arish	31°08' N	33°50' E	4.93062	5.84638	6.10926	6.16261	5.67053	5.11439	5.55983	5.71626	5.96612	5.70832	5.10876	5.09801
El Faiyum	29°19' N	30°50' E	5.14751	5.94633	6.04946	6.07928	5.45853	5.24658	5.31662	5.53184	5.96784	5.78099	5.39068	4.88944
El Giza	30°00' N	31°10' E	5.06542	5.90327	6.05035	6.11482	5.53288	5.33511	5.40028	5.59117	5.97507	5.7474	5.30885	4.78885
El Mahalla El Kubra	31°00' N	31°00' E	4.93228	5.82624	6.02594	6.16373	5.63202	5.45528	5.51134	5.66395	5.98478	5.68384	5.19703	5.03762
El Mansura	31°00' N	31°19' E	4.9363	5.83138	6.03692	6.16387	5.63551	5.45872	5.5157	5.66948	5.98378	5.68918	5.19099	5.04835
El Minya	28°07' N	30°33' E	5.28967	5.27708	6.05458	6.01343	5.32812	5.09143	5.17086	5.93202	5.95048	5.84085	5.5233	5.05738
El Suweis	29°58' N	32°31' E	5.08152	5.9234	6.09454	6.11149	5.54275	5.34425	5.41354	5.61037	5.96767	5.76817	5.28248	4.77971
Helwan	29°50' N	31°20' E	5.08873	5.91791	6.05886	6.10639	5.51758	5.3163	5.38338	5.58115	5.97265	5.75989	5.32434	4.81205
Hurghada	27°15' N	33°50' E	5.41262	5.49244	6.16465	5.95664	5.26399	5.00932	5.10535	5.86589	5.91418	5.92514	5.53529	5.13407
Ismailiya	30°37' N	32°18' E	4.996	5.87338	6.07634	6.14433	5.60687	5.42201	5.4851	5.65672	5.9756	5.72675	5.21366	4.68613
Luxor	25°41' N	32°38' E	5.58508	5.55447	6.14016	5.86606	5.07954	4.79268	4.8986	5.73867	5.89103	5.98771	5.72194	5.35459
MarsaMatruh	31°19' N	27°09' E	4.79603	5.70428	5.85866	6.15741	5.60756	5.13121	5.4811	5.60396	5.97501	5.56542	5.19145	4.82376
Qena	26°10' N	32°43' E	5.53301	5.52479	6.14084	5.89624	5.13507	4.85802	4.96013	5.77924	5.90184	5.96723	5.67389	5.29326
Sinai Peninsula	29°30' N	34°0' E	5.14218	5.96696	6.14276	6.08058	5.50569	5.29786	5.37516	5.59376	5.94817	5.80702	5.2911	4.82007
Sohag	26°33' N	31°43' E	5.48431	5.45264	6.10799	5.92202	5.16904	4.89989	4.99598	5.81035	5.91674	5.93753	5.65998	5.25656
Zagazig	30°40' N	31°30' E	4.98259	5.8593	6.04968	6.14785	5.60409	5.42027	5.48066	5.64768	5.98034	5.71271	5.22612	4.68729

- The results in Fig. 8 show estimation of daily solar radiation on a horizontal plane during year months in Giza and Fig. 9 for Aswan using Matlab/GUI Interface Program.

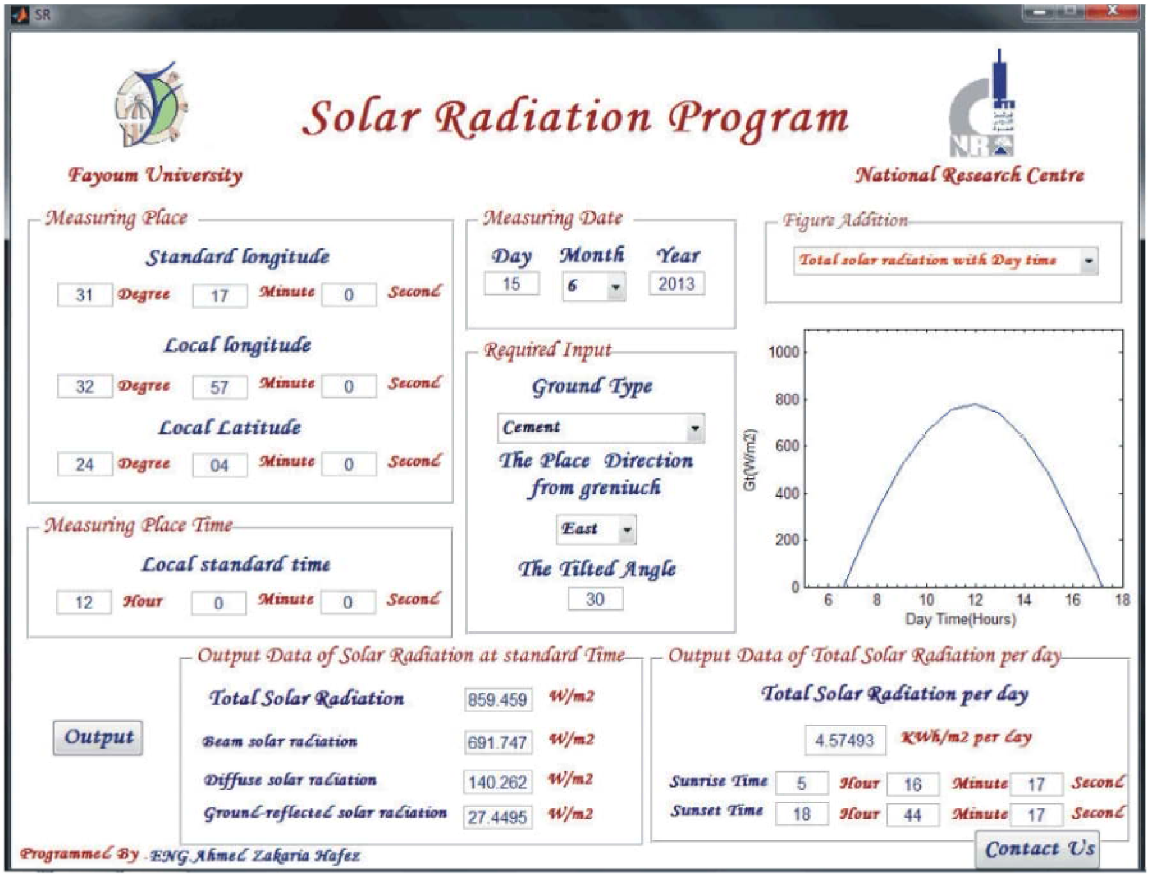


(a)

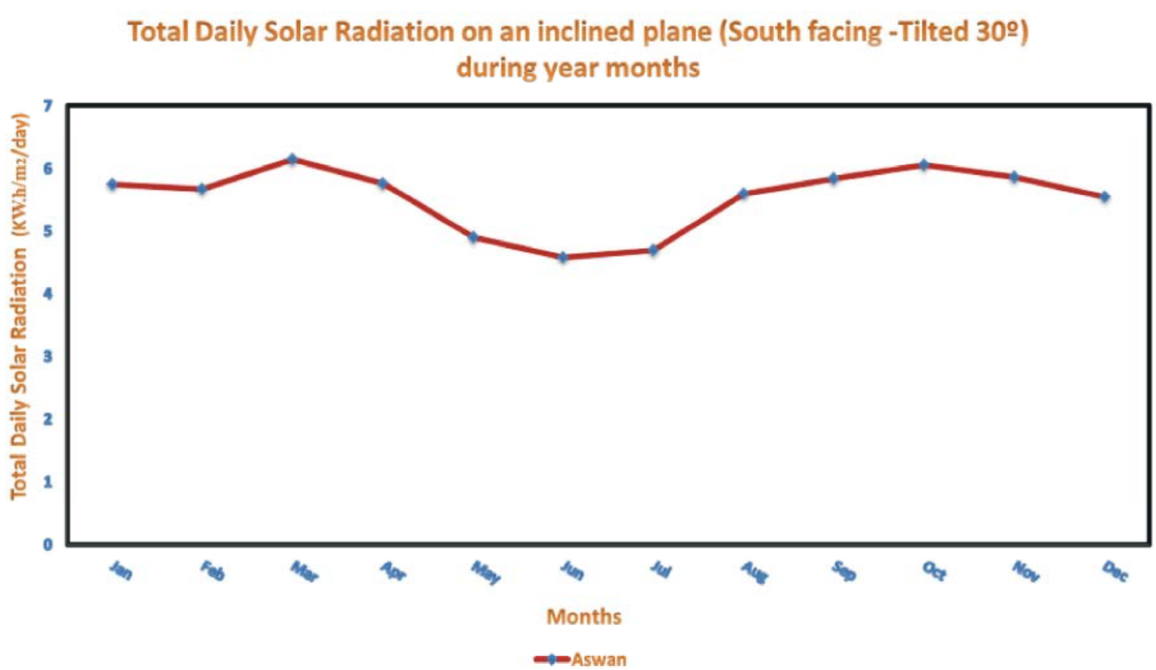


(b)

Fig. 11: Estimation of Daily Solar Radiation on an inclined plane (South facing -Tilted 30°) during year months at Giza (a) Matlab GUI/Interface simulation model (b) Solar Radiation Data during year months



(a)



(b)

Fig. 12: Estimation of Daily Solar Radiation on an inclined plane (South facing -Tilted 30°) during year months at Aswan (a) Matlab GUI/Interface simulation model (b) Solar Radiation Data during year months

Determination of Daily Solar Radiation on an Inclined Surface:

- Fig. 10 shows average daily solar radiations for thetilted surface 30° South facing during year months for the six provinces and cities"Alexandria, El Giza, Aswan, Sinai, Asyut, MarsaMatruh"of Egypt. In general, the daily values of solar global radiation/ insolation (of the locations considered in the study) range from 4.7–6.1 kWh/m^2/day.
- The daily solar radiation on an inclined plane (South facing -Tilted 30°) to be used in winter (December, January and February), in spring (March, April and May), in summer (June, July and August) and in autumn (September, October and November) for each province of Egypt are presented in Table 5. It can be depicted from Table 5 and Fig. 10 that solar radiation for the tilted surface 30°-South facing is generally higher during the year months as compared to horizontal plane.
- The results in Fig. 11 show estimation of daily solar radiation on an inclined plane (South facing -Tilted 30°) during year months in Giza and Fig. 12 for Aswan using Matlab/GUI Interface Program.

CONCLUSION

The aim of this paper is design a basic study for solar radiation calculations and data that will help designers and engineers interested in solar energy and photovoltaic applicationsin Egypt. It is well known that Egypt region has significant and unique importance due to its certain strategic site near the North Eastern borders of Africa. Solar energy applications in the field of photovoltaic and solar thermal application requires a complete knowledge and detailed analysis about the potentiality of the site for solar radiation activity. The present study uses a basic equations method and simulate it using Matlabto make appropriate site selections in order to achieve sustainable development by effective solar radiation site. Solar radiation data was simulated by MATLAB®/GUI interface software and the results are discussed. The simulation selecting the best site with best solar radiation data for photovoltaic power plants or solar thermalpower plants to have a optimize system according to solar radiation data for sites.

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Nomenclature:

LL	Local longitude, minutes
L	Local latitude, minutes
δ	The declination angle,°
h	The hour angle,°
Φ	The Zenith angle,°
z	The solar azimuth angle,°
α	The Solar altitude angle,°
α_n	The noon altitude angle,°
θ	The solar incidence angle,
**	The surface tilt angle from the horizontal,°
Z_s	The surface azimuth angle,°
h_{ss}	The hour angle at sunset in degrees,°
H_{sr}	The sunrise time in hours from local solar noon, hour
H_{ss}	The sunset time in hours from local solar noon, hour
G_{SC}	Solar constant, W/m^2
G_t	The global irradiance, W/m^2
G_{bt}	Total Beam solar radiation on a tilted surface, W/m^2
G_{dt}	Total Diffuse solar radiation on a tilted surface, W/m^2
G_{rt}	Total Ground-reflected solar radiation on a tilted surface, W/m^2
G_B	Beam radiation on a horizontal surface, W/m^2
G_{Bn}	Beam radiation in the direction of the rays, W/m^2
R_B	The beam radiation tilt factor
R_D	The diffuse radiationtilt factor
R_R	The ground-reflected radiation tilt factor
ρ	The ground reflectance, %