A Case Study Of Solar Photovoltaic Generator System At Different Locations In Algeria

Salmi Mohamed, Yarub Al-Douri

Abstract: The aim of this study is the evaluation of a photovoltaic system at different locations in Algeria. We have calculated the system efficiency, the solar energy captured by the system and the electrical energy output. An economic study of a photovoltaic station has been done by estimating the cost of this project operating for a period of 25 years. To achieve this goal, we have selected four regions of the Algerian territory, differing in their climatological parameters: Algiers, Constantine, Oran and Tamanrasset. The measured monthly global solar radiation and temperatures values are taken during six years (2000-2005) from the different meteorological stations. The obtained results have revealed that the calculated electrical power for Tamanrasset was the highest one (3581kWh), the best efficiency was in Constantine (10.3%), however the lowest cost of the project was in Algie4rs and Oran (769.7kDZ).

Index Terms— Solar Radiation; Photovoltaic's Generator, Estimation; Electrical Power; Algeria.

1 INTRODUCTION

Nowadays, the solar energy is one of the most powerful and promising renewable energies for the future. This clean energy is inexhaustible and is quite available in the majority of the world for profitable applications. Indeed, the power of solar radiation on the ground is about 950W/m2. The total amount of solar energy received at the ground during a week overtakes the energy produced by the world's reserves of petrol, coal, gas and Uranium. But in most cases, an electric conversion of the solar radiation energy is necessary. The photovoltaic electricity is obtained by the direct transformation of the solar radiation into electricity by photovoltaic cells. The photovoltaic electricity production is growing considerably since the last years exceeding 700MW/year [1]. The surface area of Algeria is over 2 million km2. It receives what is the equivalent of 300 billion of Tep/year in the form of solar energy. In terms of sunshine duration, the daily energy received over a horizontal surface of 1m2 is approximately 5kWh on almost the totality of the Algerian territory. The annual solar sunshine duration surpass 2000 hours and may achieve 3900 in the high plateaus and the Sahara [2]], which represents a high average compared with other countries in the world. The idea of using solar energy in Algeria is not new, its existence dates back at least to 1870 when the famous physicist Auguste Mouchot had proposed the creation of a lot of thermal machines for industrial and agronomic purposes [3]. A century later in 1951 a famous engineer; Maurice Touchais had installed the first solar concentrator on the site Bouzareah, Algiers.To evaluate a photovoltaic system development in Algeria and for the conversion of solar energy into electric one, we have used the RETscreen software to estimate the electric power generated by the photovoltaic (PV) systems installed in the regions of Tamanrasset, Algiers, Oran and Constantine.

- *Assoc Dr. SALMI Mohamed Department Of Physics, University Of M'sila , B.P. 1713 , M'sila 28000, Algeria E-mail: mohsalmi3@yahoo.fr*
- *Assoc. Prof. Dr. Yarub Al-Douri. Institute Of Nano Electronic Engineering (Inee) Universiti Malaysia Perlis (Unimap) E-mail: yarub@unimap.edu.my*

2 ALGERIAN METEOROLOGICAL SITES

The following data are used in this work:

2.1 Average monthly temperature measured at several meteorological stations

2.2 Average monthly global solar radiation

We took the best model obtained in the modeling of solar radiation in four areas considered in this study, namely: Algeria, Tamanrasset, Oran and Constantine (See section below) [2]. In application for the Algerian case, we have chosen four cities which represent four different regions (North, South, East and West). They are respectively: Algiers, Tamanrasset, Constantine and Oran. These areas are prototypes of the different climates of Algeria. The measured values of temperatures are obtained from the National meteorological Office - Algeria. Whereas solar radiation values are estimated using the different analytical models. The geographic coordinates of the sites are shown in the Table 1.

TABLE 1 .GEOGRAPHICAL COORDINATES OF METEOROLOGICAL SITES

Station	Latitude (deg)(N)	Altitude (m)	Longitude (deg)
Oran	35.38	99	0.37 W
Tamanrasset	22.47	1378	5.31 E
Alger	36,43	450	2.83 E
Constantine	36.17	687	6.37

2.3 Globel Solar Radiaion Models

As demonstrated in this document, the numbering for sections upper case Arabic numerals, then upper case Arabic numerals, separated by periods. Initial paragraphs after the section title are not indented. Only the initial, introductory paragraph has a drop cap.

2.2 Final Stage

The first model is a linear regression equation based on Angstrom-Prescott type [4]:

$$\frac{G}{G_0} = a + b(\frac{S}{S_0}) \quad (1)$$

The second method is a logarithmic regression model given by [5]:

$$\frac{G}{G_0} = a + b\log(\frac{S}{S_0}) \quad (2)$$

The last model is an exponential expression given by [6]:

$$\frac{G}{G_0} = a + b\exp(\frac{s}{s_0}) \quad (3)$$

Where:
G is the monthly average daily global radiation on the horizontal surface (M.Jm-2day-1);
G_0 monthly average daily extraterrestrial global radiation on a horizontal surface (M.Jm-2d-1);
S is the monthly average daily number of hours of bright sunshine;
S_0 is the monthly average daily maximum number of hours possible computed by the method of least squares;
The coefficients a and b are determined by the least squares approach;

G_0 and S_0 can be obtained from [7]:

$$G_0 = \frac{24}{\pi} I_0 (1 + 0.033\cos\frac{360n}{365})(\cos\lambda\cos\delta\sin\omega + \frac{2\pi}{360}\omega\sin\lambda\sin\delta) \quad (4)$$

$$S_0 = 2/(15ar\cos(-\tan\delta\tan\lambda)) \quad (5)$$

Where:
I_0 is the solar constant equal to 1367 Wm^{-2};
n is the day number starting from the 1st January;
δ is the solar declination;
λ is the latitude and w is the hour angle.
Table 2, resumes the best models found in this work for each station and their corresponding coefficients for each regression model.

Table 2.The best regression models and the corresponding factors

Location	Model	a	b
Algiers	2	0,646	0,68
Constantine	3	0,182	0,203
Oran	2	0,646	0,68
Tamanrasset	3	0,437	0,12

3 RETS CREEN SOFTWARE

Is an Excel-based clean energy project analysis software tool that helps decision makers quickly and inexpensively determine the technical and financial viability of potential renewable energy, energy efficiency and cogeneration projects [8]. For the evaluation of PV projects, the RETScreen contains three worksheets:

- Energy model;
- Solar resource evaluation and calculation of the charge;
- Cost analysis.

4 DISCUSSION AND RESULTS

4.1 Production and energy consumption

The table below shows the obtained results for the chosen sites:

Table 3. Obtained results using RETScreen software

	Tam.	Alger	Oran	Constantine
PV module type	**mono-Si**			
Manufacturer of PV module	**Canadian Solar/ CS6A-190M**			
Nominal efficiency of the PV module (%)	17.6			
Nominal temperature of the operating cells	°C 45			
Annual solar radiation (MJ)	23.03	15.21	18.17	16.95
Annual average temperature (°C)	22.8	19.6	18.2	15.9
Field surface of four PV modules (m^2)	4.3	4.3	4.3	4.3
Average efficiency of the inverter (%)	80	80	80	80
Various losses in PV field (%)	10	10	10	10
T Absorption rate of energy (%)	90	90	90	90
Global efficiency of PV system (%)	10	10.2	10. 2	10.3
Captured energy (kWh)	4974	3561	4184	3970
Energy supplied (kWh)	3581	2564	3012	2859

The most interesting parameter for us is the annual electric supplied energy. The calculated supplied energy in the considered sites (Constantine, Oran, Algiers and Tamanrasset) is: 2859kWh, 3012kWh, 2564kWh and 3581kWh respectively. The two last ones are in good agreement with those obtained by Saheb-Koussa and al. [9] using the Singer model, as shown in the figure (1).

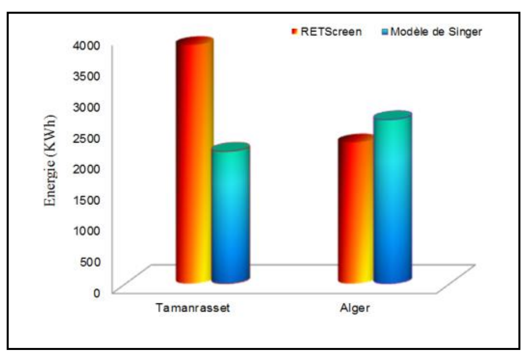

***Fig.1:**Produced annual average energy given by the two models.*

The figure (2) shows the annual energy balance of a typical home in the four considered sites. We clearly see an excess of the supplied energy which will be stocked used in the absence of sunlight.

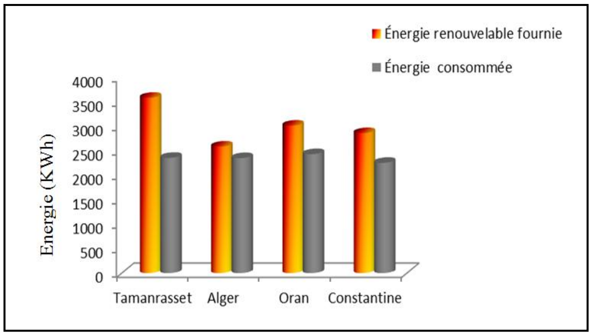

Fig. 2: Annual supplied and consumed energy

4.1 Cost analysis

The cost analysis was performed using the RETScreen software; where the current prices of solar equipments and prices of their exploitations are introduced for the considered sites during a period of 25 years of exploitation. The obtained results are mentioned in Table 4.

TABLE 4. ESTIMATED PV PROJECT COST USING RETSCREEN SOFTWARE

Equipments and exploitation	Price (kDA)			
	Constantine	Oran	Alger	Tam.
PV modules	160			
Inverter	144			
Battery	190			
Project installation	50			
Supporting structure	50			
Property taxes and insurance	10			
Maintenance	10			
Transport	120	120	100	130
Unexpected charges	35.7	35.7	34.7	36.2
Project cost (kDA)	**769,7**	**769,7**	**748,7**	**780,2**

The figure (3) shows a comparison of the invested costs of the project with the Algerian company of electricity distribution (SDE), taking in consideration that the unit price of 1kWh is 4.179 KDA.

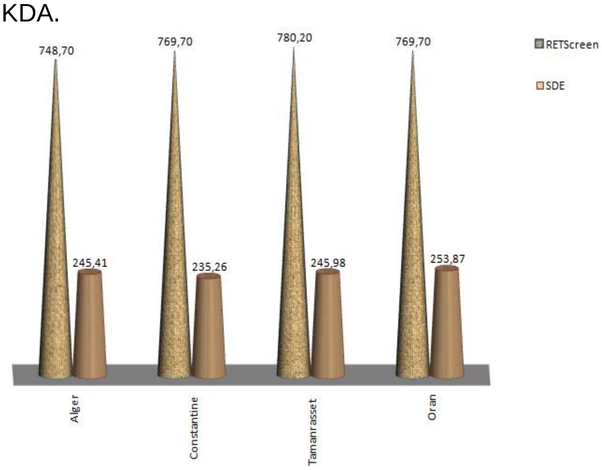

Fig. 3: Comparison of the coste (in KDA) of PV project estimated by RETScreen qnd the CED costs.

It should be noted that the big difference between the two costs is due to higher prices of solar equipments. However, from energy point of view, a considerable gain of supplied energy calculated by RETScreen is obtained for the different considered regions: Tamanrasset 20715kWh, Algiers 5375kWh, Oran 14550kWh and Constantine 15180kWh.

4 CONCLUSION

The above estimative study using the RETScreen software has led to the following conclusions: 1) The performance of photovoltaic systems is strongly affected by the incident radiation. 2) The power estimated by the RETScreen was highest for the city of Tamanrasset (3581 KWh). 3) The best performance of the PV system (10.3%) is obtained for Constantine city. 4) The estimated project costs of PV system (equipments and installation) for 25 years exploitation for the four cities: Tamanrasset, Algiers, Oran and Constantine are respectively: 780.2 KDZ, 748.7 KDZ, 769.7 KDZ and 769.7 KDZ. In spite of the higher costs of the PV equipments, a considerable gain of energy supplied is obtained.

ACKNOWLEDGMENT

This research was carried out within the framework of a national project entitled “influence of climate parameters on the performance of photovoltaic systems” funded by the Algerian Ministry of Higher Education and Scientific Research.

REFERENCES

[1] C. J. K. Kaldellis, “Optimum techno-economic energy autonomous photovoltaic solution for remote consumers throughout Greece, ” Energ. Convers. Mgmt, vol. 45, N°17, pp. 2745-2760, October 2004.

[2] M. . Salmi, M. Chegaar, and P. Mialhe, “A Collection of Models for the Estimation of Global Solar Radiation in Algeria, ”.Energy Sources, Part B: Economics, Planning, and Policy, vol. 6, pp.187–191, April 2011.

[3] A. Mouchot, La chaleur solaire et ses applications industrielles, Gauthier et Villars, 1869.

[4] A. Angström, “Solar and terrestrial radiation”. Quart.J. Roy Met. Soc. vol. 50, pp.121.124, 1924

[5] D. B Ampratwum and A. Dorvlo, “Estimation of solar radiation from the number of sunshine hours”. Applied Energy, vol. 63, pp. 161-167, July 1999.

[6] J. Almorox and C. Hontoria, “Global solar estimation using sunshine duration in Spain” , Energ. Convers. Mgmt, vol. 45, pp. 1529-1535, june 2004.

[7] O. Galip, H. Arif and G. Asir, “Statistical Analysis of Solar Radiation Data”. Energy Sources, vol. 25, pp.1089-1097, 2003.

[8] G. J. Leng, U. T. Ziegier, N. Meioche, D. S. Parakh, Logiciel RETScreen, Ministre de Ressources naturelles Canada, 2006.

[9] D. Saheb-Koussa, M. Belhamel, and K. Benferhat: “Contribution à l’étude théorique du comportement d’un système hybride (éolien- photovoltaïque- diesel) de production d’électricité sans interruption”. Afrique Science, vol. 5, pp.23–38 , January 2009.