International Journal of Engineering Sciences & Research Technology

(A Peer Reviewed Online Journal)
Impact Factor: 5.164

IJESRT

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

PERFORMANCES OF SILICON SOLAR MODULES IN TOGO'S MAIN CITIES AS A FUNCTION OF IRRADIATION AND TEMPERATURE

Yendoube Lare[1,2], Kanlanféi Sambiani[1,2], Moyème Kabe[1] & Kokou Amega[1,2]
[1]Solar Energy Laboratory, Physics' Department, Faculty of Sciences, University of Lomé, Togo
[2]West African Science Service Centre on Climate Change and Adapted Land Use (Wascal), University Abdou Moumouni of Niamey, Niger

DOI: https://doi.org/10.29121/ijesrt.v10.i10.2021.4

ABSTRACT

This work presents the study of the functional electrical characteristics of silicon solar modules in each of the five regional capitals in Togo, as a function of irradiation and temperature. Simulation of electrical characteristics of the three main types of silicon modules (monocrystalline, polycrystalline and amorphous) are performed in Simulink of Matlab 2019a, using temperature and irradiation data of the five regional capitals in Togo (Lomé, Atakpamé, Sokodé, Kara and Dapaong). The I-V, P-V and performance ratio (PR) results showed that the modules that would have the best performance ratio is amorphous silicon but the polycrystalline are the best compromise taking into account the power generated and the modules' prices. It also emerges that the most suitable city to install photovoltaic power plants would be Dapaong.

KEYWORDS: silicon photovoltaic modules, electrical characteristics, irradiation and temperature, matlab/Simulink.

1. INTRODUCTION

Since the industrial revolution, most of humanity's modern energy needs is assured through the use of fossil fuels such as oil, coal, natural gas or nuclear energy. These resources are becoming increasingly scarce, while the world's energy demand is steadily rising according to statistics ; so that commercial primary energy consumption is expected to double by 2030 and then triple on the horizon 2050 [1]. It is estimated that world's fossil fuels reserves will be depleted by 2030 if consumption is not radically changed, and at most by 2100 if efforts are made on production and consumption [1]. In addition, the increased use of these fossil resources causes a lot of damage to the environment and is the principal cause of climate change. Since this form of energy covers a large part of the current energy production, it appeared necessary to find another solution to take over; the constraint imposed is to use a cheap energy source that engenders low pollution because the protection of the environment has become an important point. In this respect, renewable energies, such as solar photovoltaic, wind or hydroelectric appear as inexhaustible and easily exploitable. For instance, in the case of solar photovoltaic, a surface of 145 000 km² (4 % of the surface of the deserts arid) of photovoltaic panels would be sufficient to cover all the energy needs of the humanity [1].

In the latter case, the design, optimization and realization of photovoltaic (PV) power plants are typical problems since they surely lead to a better exploitation of solar energy. For a photovoltaic installation, the variation of the radiation or temperature induces a degradation of the power supplied by the photovoltaic generator. In addition, it no longer works in optimal conditions. The optimization of solar systems is based on sizing criteria and maximizing the power generated to have a good performance.

In this work, we decided to focus on simulating the electrical characteristics of different photovoltaic silicon modules in each of Togo's five regional capital in function of irradiation and temperature, in order to find, on the one hand, the technology best adapted to local atmospheric conditions, and on the other hand the most suitable city for photovoltaic power plants installation. Our choice to study the performance of silicon photovoltaic

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

modules as a function of irradiation and temperature only, far from signifying an ignorance of other external parameters that can influence the actual performance of photovoltaic modules, constitutes a deliberate choice and a first step of a comprehensive approach, the objective of which is to ideally examine, when all the other conditions are met, the technology that would be most suitable for our cities and the city that would be most suitable for large-scale solar installations, regarding only irradiation and temperature. Indeed, the effective operating efficiency of a PV module depends on some other parameters which range from the details of installation (inclination angle, possible shadows) to

The wind speed and the probability of dust or snow deposition [2-4]. Our objective in this study was to give a first overview, taking into account only the two main parameters that are irradiation and temperature, the goal being to help the actors of the sector in the choice of technologies and sites for photovoltaic installations in order to optimize the exploitation of this technology in our country.

2. MATERIALS AND METHODS

2.1. Geographic site

This study took into account the five (05) main cities representing the five regional capitals in Togo, namely: Lomé (Maritime Region), Atakpamé (Plateaux Region), Sokodé (Centrale Region), Kara (Kara Region), Dapaong (Savanna Region).

The altitude, latitude and longitude of meteorological stations in these cities are shown in Table 1.

Table 1: Geographical data of the cities of the study

Cities	Longitude	Latitude	Altitude (m)
Lomé	1.25 ° E	6.17 ° N	15
Atakpamé	1.12 ° E	7.58 ° N	201
Sokodé	1.147 ° E	8.978 ° N	367
Kara	1.193 ° E	9.547 ° N	402
Dapaong	0.201 ° E	10.873 ° N	245

2.2. Description of available meteorological data

The basic ambient conditions to be considered in the study of a photovoltaic system are: solar radiation and temperature. Theses parameters were collected from the National Directorate of Meteorology of Togo. The data consisted in daily average temperature and daily average solar radiation on horizontal surface, over ten years (2010-2020) for a good representation of these parameters of the cities. As our study aims to make a qualitative comparative analysis, we assume that these parameters are those actually received by the modules even if we are well aware that in reality, the modules will be tilted and will not receive the same amount of radiation and that their temperature will probably be higher than ambient ones.

The daily average ambient temperatures of the different cities are shown in Table 2.

Table 2: Average ambient temperature of the study sites

Cities	Lomé	Atakpamé	Sokodé	Kara	Dapaong
Temperature (° C)	28.4	27.1	27.2	27.9	28.7

The average daily values of solar radiation for the different sites are reported in Table 3. These values indicate that the solar potential is quite high and is practically usable during the whole year.

Table 3: average daily irradiation of the different sites

Cities	Lomé	Atakpamé	Sokodé	Kara	Dapaong
Irradiation (W/m^2)	441.08	450.48	496.94	467.57	480.17

2.3. Simulation and analysis of photovoltaic generator efficiency under atmospheric conditions

2.3.1. Electrical model of photovoltaic modules

To define the model of a photovoltaic module, it is first necessary to present the equivalent electric circuit of a PV cell. Numerous electric models have been developed to represent their very strongly nonlinear behavior that results from that of the semiconductor junctions, which constitute the base of their achievements. We present here the two main models encountered in the literature [5]: the single-diode model and the two-diode model.

a. Single diode model

The operation of a photovoltaic cell described by the "standard" model of a diode, established by Shokley for a single PV cell, is generalized to a PV module, considering it as a set of identical cells connected in series or in parallel (Figure 1) [6].

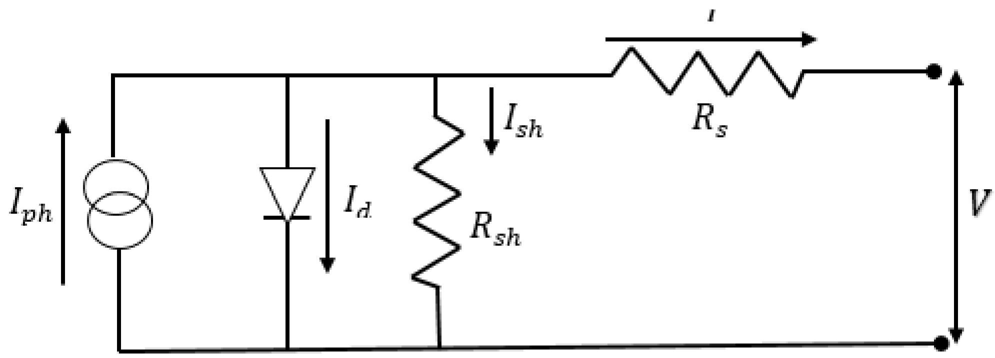


Figure 1: Electrical model of single-diode PV Module

The current I supplied by the cell is given, in terms of the voltage V, the resistors R_s and R_{sh}, the saturation current of the diode I_d, the photocurrent I_{ph}, the absolute electrical charge q of the electron, the number N_s of cells in series and the cell temperature T, by the relation [6]:

$$I = I_{ph} - \frac{V+R_s\times I}{R_{sh}} - I_d\left[\exp\left(\frac{q(V-R_s\times I)}{N\times k_B\times T\times N_s}\right) - 1\right] \quad (1)$$

where N is the ideality factor of the diode and k_B is the Boltzmann constant. The two resistors R_s and R_{sh} are related to electrode development technology. The saturation current of the diode is assumed to be variable with temperature. The parameters of this model are then: the series resistor R_s, the shunt resistor R_{sh}, the photocurrent I_{ph}, the saturation current of the diode I_d and the ideality factor N.

b. Two diodes model

In this case, there are two diodes to represent the polarization phenomena of the PN junction. These diodes symbolize the recombination of the minority carriers, on the one hand on the surface of the material and on the other hand in the volume of the material [7]. Figure 2 shows the two diodes electrical model.

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

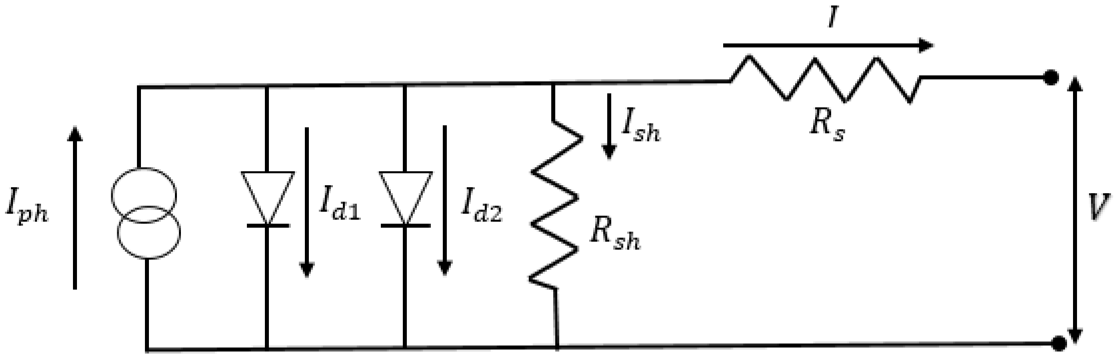


Figure 2: Electrical model of two-diodes PV Module

The following relation gives the current supplied by the cell [7]:

$$I = I_{ph} - \frac{V+R_s\times I}{R_{sh}} - I_{d1}\left[\exp\left(\frac{q(V-R_s\times I)}{N_1\times k_B\times T\times N_s}\right)-1\right] - I_{d2}\left[\exp\left(\frac{q(V-R_s\times I)}{N_2\times k_B\times T\times N_s}\right)-1\right] \quad (2)$$

where N_1 is the ideality factor of the first diode and N_2 that of the second diode.

Among these mathematical models, the one with single diode is generally considered as the most suitable and the easiest to implement to model a photovoltaic cell in normal functioning [8-13].

2.3.2. Implementation of the photovoltaic panel model in Matlab Simulink environment

Equation (1) is an implicit equation containing I and V which can be solved thanks to the Simulink program with five parameters $\boldsymbol{I_{ph}}$, $\boldsymbol{I_d}$, $\boldsymbol{N}$, $\boldsymbol{R_s}$ and $\boldsymbol{R_{sh}}$, considered. In practice, the informations provided by the manufacturers on the characteristics concern only the modules and are determined under particular conditions namely the standard tests conditions (STC) (G = 1000 W/m^2, T =25 °C).

The information flow of a solar panel can be divided into three main groups which are: settings, inputs and outputs:

- **The settings :**
  - Number of cells in series $\boldsymbol{N_s}$ in the module,
  - Open-circuit voltage $\boldsymbol{V_{oc}}$ of each module in volts,
  - Short circuit intensity $\boldsymbol{I_{sc}}$ of each module in Ampere,
  - Ideality factor of module $\boldsymbol{N}$,
  - Temperature coefficient for open-circuit voltage **CN** ;
- **The inputs:**
  - Solar irradiance $\boldsymbol{G}$
  - Ambient temperature $\boldsymbol{T}$;
- **The outputs:**
  - the intensity $\boldsymbol{I}$ delivered by the module,
  - The voltage $\boldsymbol{V}$ delivered by the module,
  - The power $\boldsymbol{P}$ delivered by the module ;

This set of information is organized in the information flow diagram under Simulink as shown in Figure **3.**

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

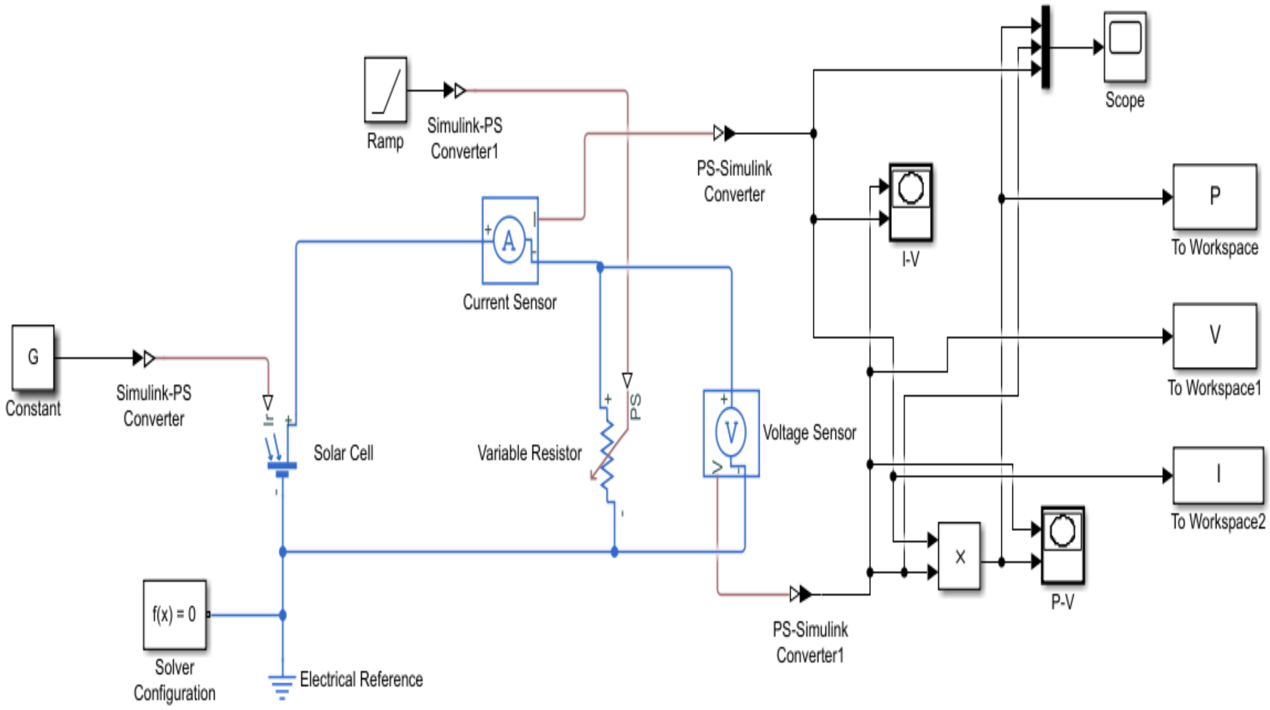


Figure 3: flowchart of the photovoltaic module with Simulink block

2.3.3. Efficiency calculation

At the maximum power point, the energy efficiency without the control of the Maximum Power Point Tracker (MPPT) is written [14], [15] :

$$\eta = \frac{P_m}{S \times P_{inc}} \quad (3)$$

with $\boldsymbol{P_{inc}}$ the incident power and $\boldsymbol{S}$ the surface of the photovoltaic cell.

2.3.4. Photovoltaic performance ratio

*In order to be able to make an appropriate module choice analysis in different environments, the introduction of a performance ratio (**PR**) of the module is necessary to quantify the efficiency variations according to real conditions. The photovoltaic performance ratio is the ratio between the actual efficiency in operating situation and the efficiency under standard conditions (STC) [16] :*

$$PR = \frac{\eta(\%)}{\eta(\%)STC} \quad (4)$$

where $\boldsymbol{\eta}$ (%) STC is the efficiency of the module under STC conditions and $\boldsymbol{\eta}$ (%) the actual efficiency in geographic conditions.

3. RESULTS AND DISCUSSIONS

Photovoltaic modules are differentiated by several criteria among which we can list: the material, the technology, the peak power and the manufacturers. For simulation, we considered the following data obtained from PVsyst software of three types of modules existing on the national market in Togo to highlight the most suitable for different meteorological sites or cities: monocrystalline silicon module " JKM 205M-72/205 W ", polycrystalline silicon module " JKM 205PP-48/205 W " and amorphous silicon module " ECO-SR92/92 W ". Their electrical characteristics under standard test conditions-STC (G = 1000 W / m², T = 25 ° C and AM = 1.5) are given respectively in Tables 4, 5 and 6.

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

Table 4: Electrical characteristics of JKM 205M-72 / 205W monocrystalline module

Module technology	Monocrystalline
Maximum power of the module P_m	*205 W*
Open circuit voltage V_{oc}	45.9 V
Short-circuit current I_{cc}	5.90 A
Maximum operating current I_m	5.51 A
Maximum operating voltage V_m	37.2 V
Cells per module N_s	*72*
Temperature coefficient for open circuit voltage K_V	-152 mV/°C
Temperature coefficient for the short-circuit current K_i	3.0 mA/°C
Serial resitance **Rs**	*0.59*
Ideal factor **N**	1.02
Surface **S**	1.28 m²
Yield/surface module	16.1%

Table 5: Electrical characteristics of JKM 205PP-48/ 205 W polycrystalline module

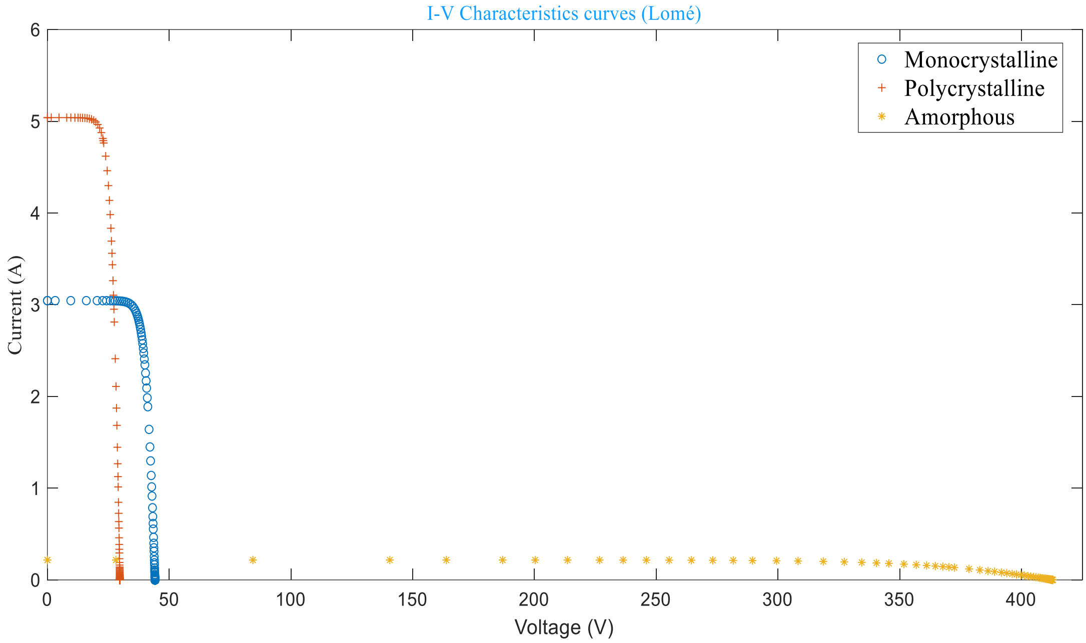
Module technology	Polycrystalline
Maximum power of the module P_m	*205 W*
Open circuit voltage V_{oc}	31.2 V
Short-circuit current I_{cc}	9.49 A
Maximum operating current I_m	8.30 A
Maximum operating voltage V_m	24.7 V
Cells per module N_s	*48*
Temperature coefficient for open circuit voltage K_V	-94 mV/°C
Temperature coefficient for the short-circuit current K_i	5.7 mA/°C
Serial resitance **Rs**	*0.32*
Ideal factor **N**	1.45
Surface **S**	1.31 m²
Yield/surface module	15.7 %

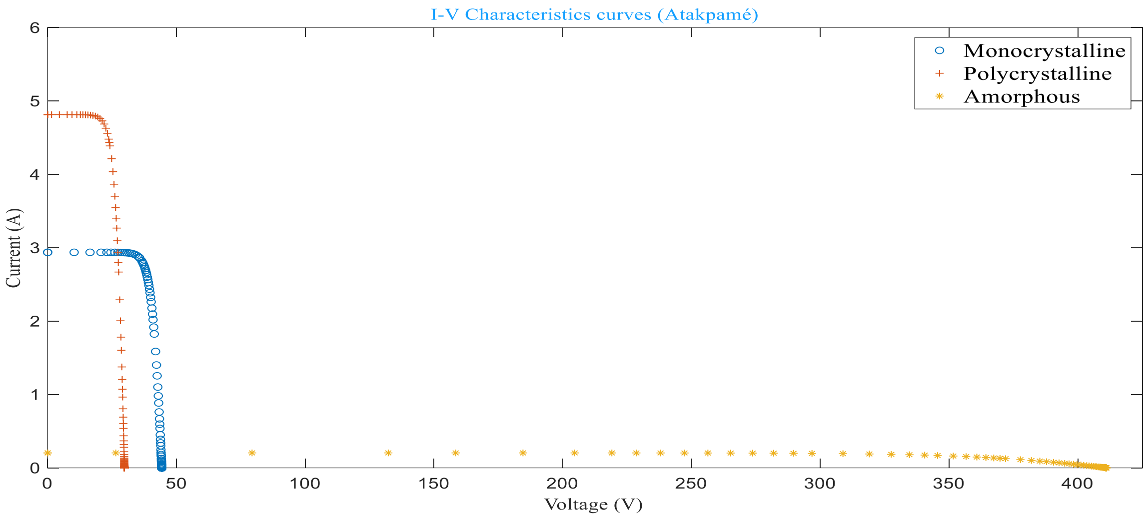
Table 6: Electrical Characteristics of ECO-SR92 / 92 W amorphous silicon module

Module technology	Amorphous silicon
Maximum power of the module P_m	*92 W*
Open circuit voltage V_{oc}	429.0 V
Short-circuit current I_{cc}	0.39 A
Maximum operating current I_m	0.29 A
Maximum operating voltage V_m	319.0 V
Cells per module N_s	*320*
Temperature coefficient for open circuit voltage K_V	-1105 mV/°C
Temperature coefficient for the short-circuit current K_i	0.3 mA/°C
Serial resitance **Rs**	*100*
Ideal factor **N**	3.36
Surface **S**	1.58 m²
Yield/surface module	5.8 %

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

The work consisted in simulating the three types of modules in meteorological conditions of the cities, based on the average ambient temperature (Table 2), and average daily irradiation (Table 3) of different sites. Figures 4 and 5 show respectively the current-voltage (I-V) and power-voltage (P-V) characteristics of the different sites.





ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

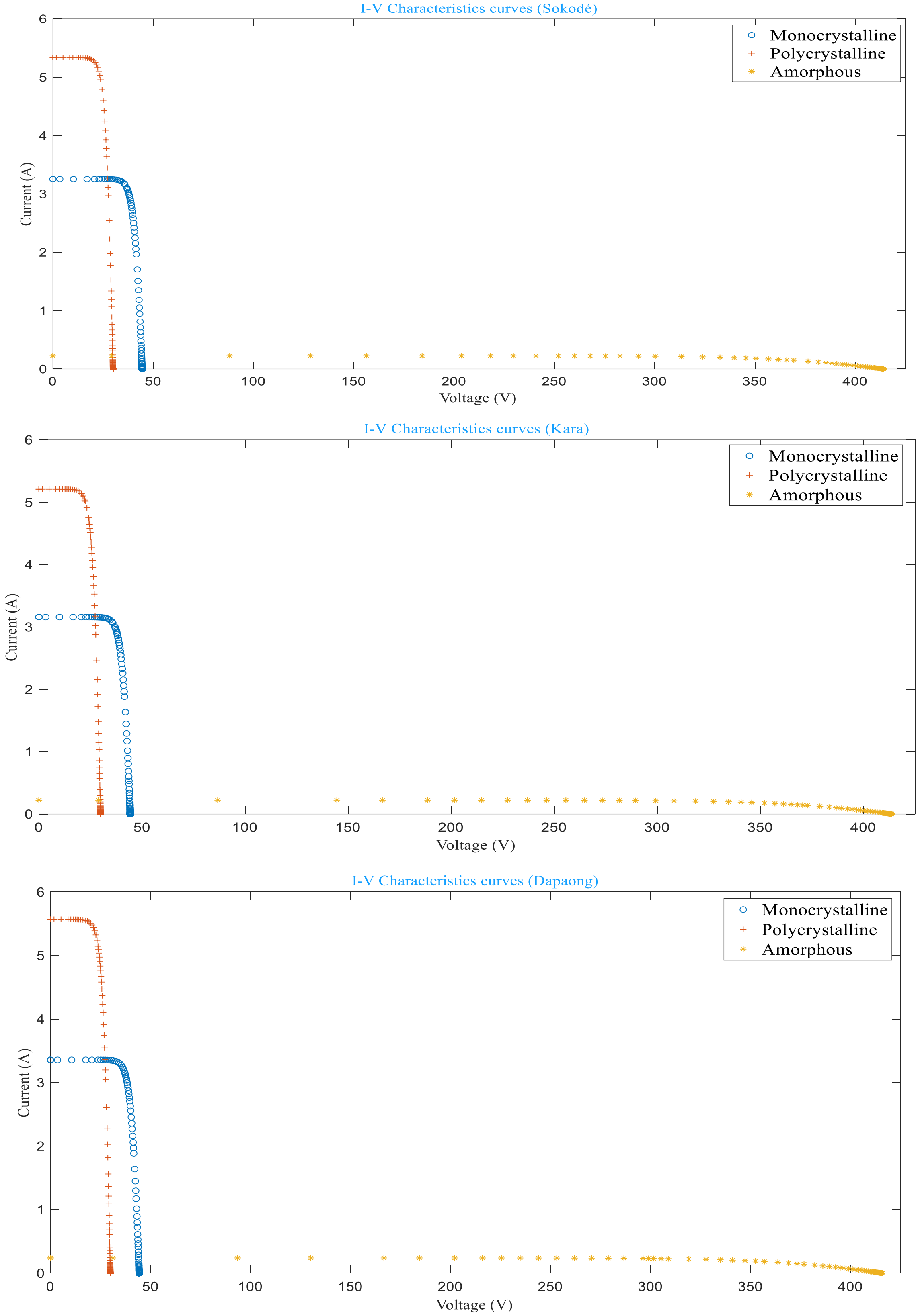
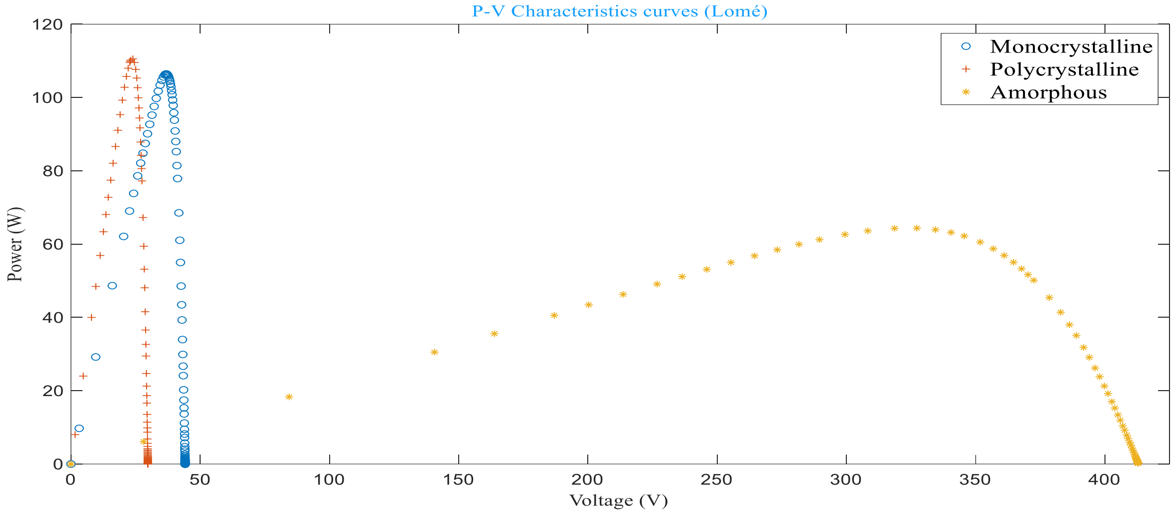
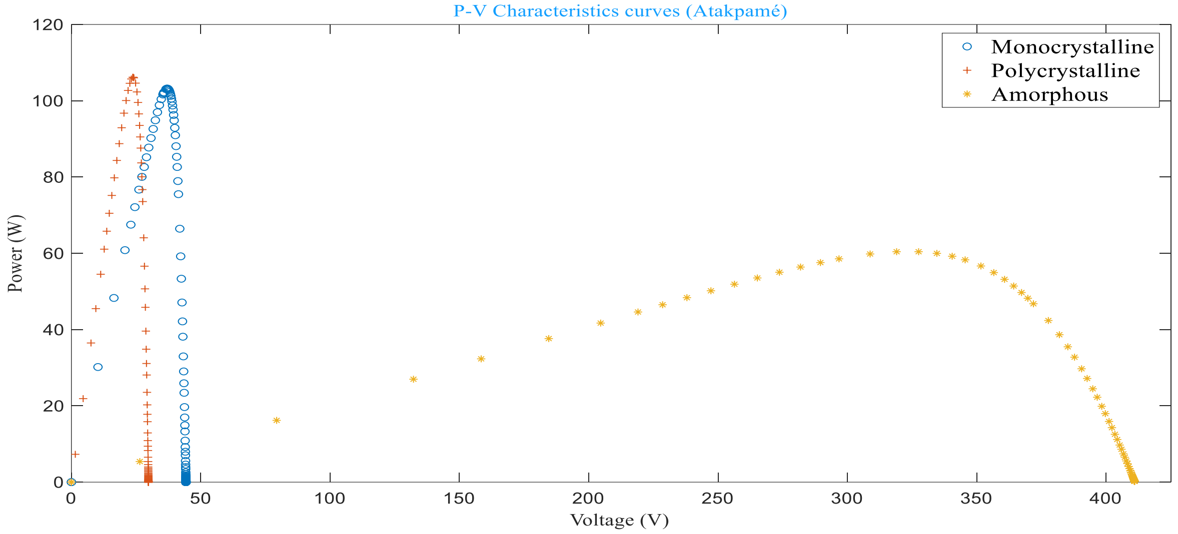
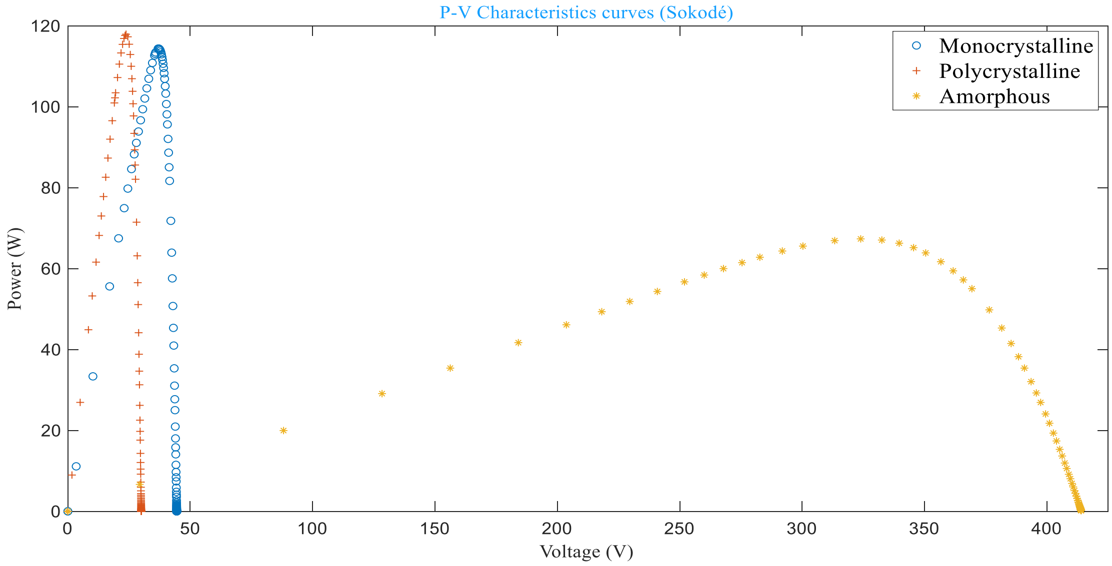


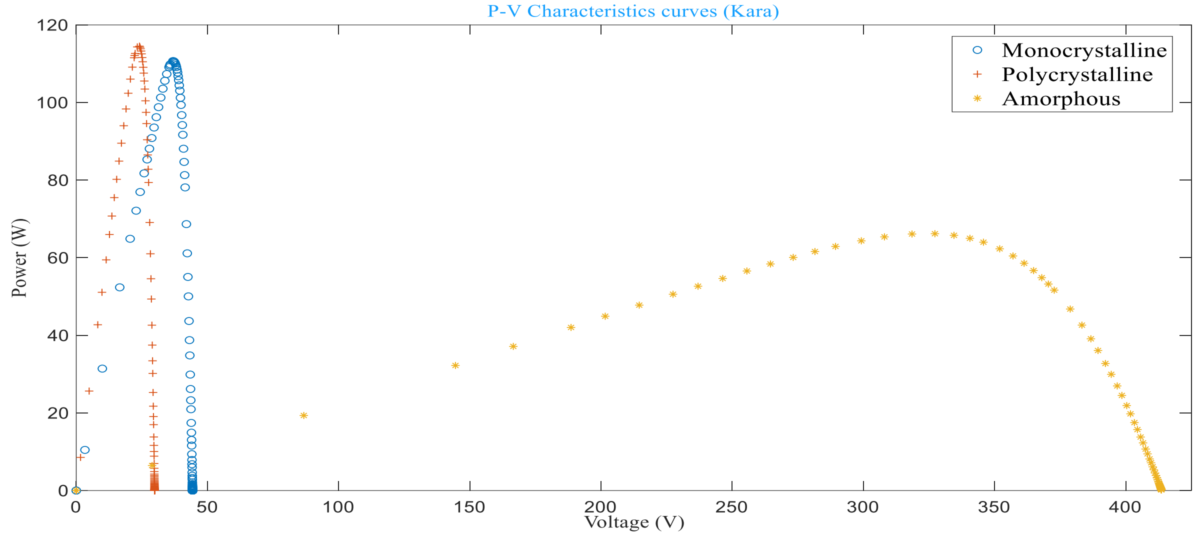
Figure 4: I-V Characteristics of the modules for the five main cities

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7









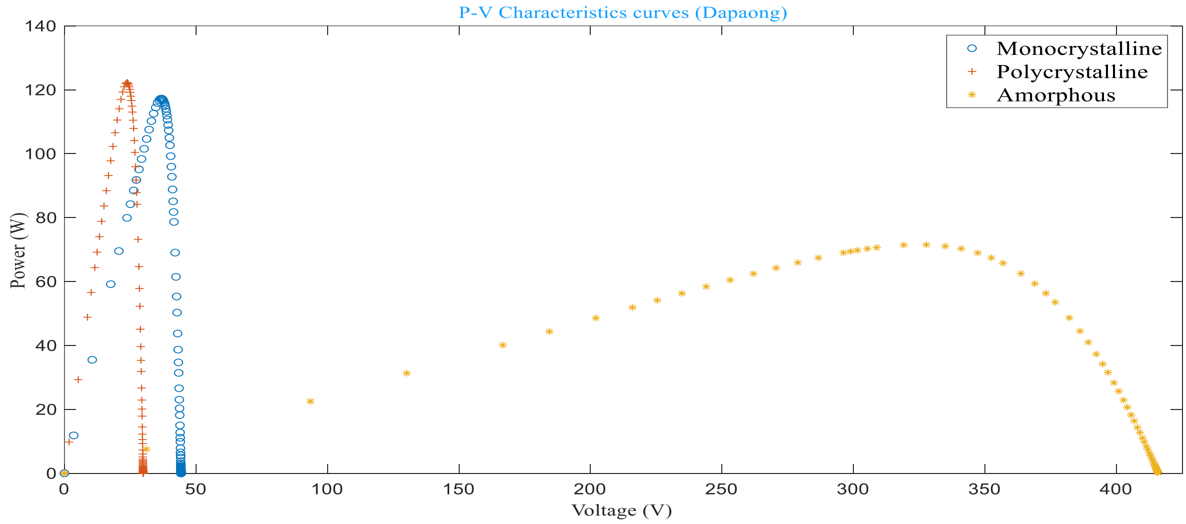


Figure 5: P-V characteristics of the modules for the five main cities

From these characteristics obtained with the horizontal radiation and ambient temperature of different sites, we deduced the maximum power and the efficiency of each module in the cities. The values of both parameters are shown in table 7.

Table 7: Efficiency of modules for the five main cities

Cities or sites	P_{inc} (W/m²)	types of modules					
		Monocrystalline $S = 1.28$ m².		Polycrystalline $S = 1.31$ m²		Amorphous silicon $S = 1.58$ m²	
		P_m (W)	η (%)	P_m (W)	η (%)	P_m (W)	η (%)
Lomé	441.08	106.42	18.84	110.55	19.13	64.35	9.23
Atakpamé	450.48	103.20	17.89	106.16	17.98	60.42	8.48
Sokodé	496.94	114.38	17.98	117.92	18.11	67.33	8.57
Kara	467.57	110.66	18.49	114.52	18.69	66.19	8.95
Dapaong	480.17	117.23	19.07	122.25	19.43	71.49	9.42

The manufacturer's data (peak power, surface and efficiency) of the modules, obtained from PVsyst software are reminded in table 8.

Table 8: Efficiency of the modules in STC

types of modules	P_m (W) dans STC	Module surface S (m²)	η (%) STC
Monocrystalline	*205*	1.28	16.1
Polycristalline	*205*	1.31	15.7
Amorphous silicon	*92*	1.58	5.8

Module's Performance ratios (PR) of the cities, calculated from efficiency data from tables 7 and 8, are shown in table 9.

Table 9: Module's Performance Ratio for different cities

		Lomé	Atakpamé	Sokodé	Kara	Dapaong
Monocrystalline	η (%)	18.84	17.89	17.98	18.49	19.07
	PR	1.17	1.11	1.12	1.15	1.18
Polycrystalline	η (%)	19.13	17.98	18.11	18.69	19.43
	PR	1.22	1.14	1.15	1.19	1.24
Amorphous silicon	η (%)	9.23	8.48	8.57	8.95	9.42
	PR	1.59	1.46	1.47	1.54	1.62

The power of a photovoltaic installation depends on two main meteorological parameters which are solar radiation and temperature. Thus, the best parameter that can be used to compare module operating performance is the performance ratio which expresses the ratio of the actual and theoretically possible energy outputs [17-20]. This parameter therefore makes it possible to realize the actual efficiency of modules under given atmospheric conditions and to compare them in order to determine the most efficient in terms of conversion of the incident radiation. Table 7 show that the polycrystalline silicon (JKM 205PP-48) efficiency values are higher than monocrystalline silicon (JKM 205M-72) and amorphous silicon (ECO-SR92) for each city. It also lets see that for Atakpamé, Sokodé and Kara, the efficiency values for each silicon technology are respectively lower than those of Lomé and Dapaong. This means that Lomé and Dapaong have good climatic conditions to get the important performances in these solar panel operating. Therefore, with the photovoltaic efficiency approach, it could be concluded that Dapaong is the best city to make a solar plant in Togo.

However, the best approach to compare the performance of PV modules is the performance ratio [16]. The values of this parameter for each silicon technology used in this study are shown in table 9. It can be noted that the PR values of the amorphous silicon (ECO-SR92) are higher than those of polycrystalline silicon (JKM 205PP-48) and monocrystalline silicon (JKM 205M-72) respectively for all cities. This could be explained by the fact that in low irradiation where diffuse radiations are preponderant, this technology present the best performance. Mohand Kaci et al. found, in a comparative study of the performances of photovoltaic modules, that generally the amorphous silicon present the best PR under the low irradiation conditions which give an important blue radiation between 446 – 500 nm [16]. These results can be explained by the global climate in Togo which is tropical type with often cloudy skies causing a lot of diffuse radiations [21] reducing the direct irradiation that participates in the photovoltaic effect.

In addition, the comparison of (I-V) and (P-V) characteristics curves on figures 4 and 5 for each city, shows that the maximal current and power generated by the polycrystalline silicon are more important than those generated by the monocrystalline followed by the amorphous silicon. For Dapaong, the best city to install solar plant, we obtained 5.56 A and 122.25 W for polycrystalline silicon, 3.35 A and 117.23 W for monocrystalline silicon, 0.24 A and 71.49 W for amorphous silicon. From all these above results we could do a good compromise by taking

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

into account the energy generated by the technologies and their cost, which would lead to a choice for the polycrystalline silicon like the best technology for each city.

4. CONCLUSION

In this work, we simulated in Simulink of Matlab, the operating characteristics of the three main silicon module technologies for the five regional capitals in Togo. We have come up with the type of module most suited to our environment and the most suitable city for large-scale solar installations. It appeared that polycrystalline modules are to be recommended in our environment which is globally a tropical type climate and that the city of Dapaong would be the city where photovoltaic solar plants would be the most profitable, because of its best solar irradiation – ambient temperature compromise. The results of this work can therefore validly guide the actors of the photovoltaic field in Togo in the choice of technologies to be installed according to the needs and in the choice of cities as well.

REFERENCES

[1] K. Kassmi et M. Hamdaoui, « Conception et modélisation d'un système photovoltaïque adapté par une commande MPPT analogique », p. 12.
[2] Environmental Impacts on the Performance of Solar Photovoltaic Systems. Ramadan J. Mustafa , Mohamed R. Gomaa , Mujahed Al-Dhaifallah, and Hegazy Rezk. Sustainability 2020, 12, 608
[3] The effect of weather conditions on the efficiency of PV panels in the southeast of UK. Sanaz Ghazi a, Kenneth Ip. Renewable Energy 69 (2014) 50-59
[4] Performance evaluation of a PV module under climatic conditions of Dhahran, Saudi Arabia. Haitham Bahaidarah, Shafiqur Rehman, Abdul Subhan, P. Gandhidasan1 and Hasan Baig. ENERGY EXPLORATION & EXPLOITATION · Volume 33 · Number 6 · 2015 pp. 909–930
[5] L. Abbassen, « Etude de la connexion au réseau électrique d'une centrale photovoltaïque », PhD Thesis, Université Mouloud Mammeri, 2011.
[6] [6] [En ligne]. Disponible sur: http://www.outilssolaires.com/glossaire/prin-1geometrie.html.
[7] S. Abada, « Étude et optimisation d'un générateur photovoltaïque pour la recharge d'une batterie avec un convertisseur Sepic », p. 144.
[8] A. Yahfdhou, M. M. Menou, A. M. Yahya, Ne. D. Eida, A. K. Mahmoud, et I. Youm, « Valuation and Determination of Seven and Five Parameters of Photovoltaic Generator by Iterative Method », Smart Grid Renew. Energy, vol. 07, no 09, p. 247-260, 2016, doi: 10.4236/sgre.2016.79019.
[9] Rezaee Jordehi, A., 2018, "Enhanced Leader Particle Swarm Optimisation (ELPSO): An Efficient Algorithm for Parameter Estimation of Photovoltaic (P-V) Cells and Modules," Sol. Energy, 159, pp. 78–87.
[10] Kumari, P. A., and Geethanjali, P., 2018, "Parameter Estimation for Photovoltaic System under Normal and Partial Shading Conditions: A Survey," Renew. Sustain. Energy Rev., 84.
[11] Chen, W., Wu, Y., Yue, Y., Liu, J., Zhang, W., Yang, X., Chen, H., Bi, E., Ashraful, I., Grätzel, M., and Han, L., 2015, "Efficient and Stable Large-Area Perovskite Solar Cells with Inorganic Charge Extraction Layers," Science (80-.)., 350(6263), pp. 944–948.
[12] Tchoketch_Kebir, S., 2020, "Study of a New Hybrid Optimization-Based Method for Obtaining Parameter Values of Solar Cells," Solar Cells [Working Title], IntechOpen, pp. 137–144.
[13] Kumara, I. N. S., Ashari, M., Sampeallo, A. S., and Pawitra, A. A. G. A., 2017, "Simulated Energy Production and Performance Ratio of 5 MW Grid - Connected Photovoltaic under Tropical Savannah Climate in Kupang Timor Island of Indonesia," pp. 117–129.
[14] D. L. Staebler et C. R. Wronski, « Reversible conductivity changes in discharge-produced amorphous Si », Appl. Phys. Lett., vol. 31, no 4, p. 292-294, août 1977, doi: 10.1063/1.89674.
[15] M. Arrouf, « Optimisation de l'ensemble onduleur, moteur et pompe branché sur un générateur photovoltaique », 2007.
[16] G. M. Kaci, A. Mahrane, et M. Chikh, « Etude comparative des performances de modules photovoltaïques de différentes technologies dans un climat méditerranéen », p. 10.
[17] M. Gürtürk, H. Benli, et N. K. Ertürk, « Determination of the effects of temperature changes on solar glass used in photovoltaic modules », Renew. Energy, vol. 145, p. 711-724, janv. 2020, doi: 10.1016/j.renene.2019.06.091.

[18] H. El Achouby, M. Zaimi, A. Ibral, et E. M. Assaid, « New analytical approach for modelling effects of temperature and irradiance on physical parameters of photovoltaic solar module », Energy Convers. Manag., vol. 177, p. 258-271, déc. 2018, doi: 10.1016/j.enconman.2018.09.054.
[19] J. Zaraket, T. Khalil, M. Aillerie, G. A. Vokas, et C. Salame, « The Effect of Electrical stress under temperature in the characteristics of PV Solar Modules », Energy Procedia, vol. 119, p. 579-601, juill. 2017, doi: 10.1016/j.egypro.2017.07.083.
[20] Z. A. Jaffery et A. Haque, « Temperature measurement of solar module in outdoor operating conditions using thermal imaging », Infrared Phys. Technol., vol. 92, p. 134-138, 2018.
[21] M. Mussard et M. Amara, « Performance of solar photovoltaic modules under arid climatic conditions: A review », Sol. Energy, vol. 174, p. 409-421, 2018..