ICREN-01/2013 February 16-17, 2013 Constantine, Algeria
First International Conference on Renewable Energies and Nanotechnology impact on Medicine and Ecology

Simulation of photovoltaique system integrated in Building

Karamostefa-Khelil Cherifa[a],Hamidat Abdrahmane[b]

[a]*Elctronic departement, soumaa road, Blida09000, Algeria*
[b]*Centre des enenrgies renouvlables, Bouzerea, Algiers16000, Algeria*

Abstract

The production of electricity using solar photovoltaic energy is one of the solutions for reduction of gas emission in the atmosphere and prevent against greenhouse effect. In addition of a rural application, the growth of using this energy is becoming more interesting in industrial countries. The advantage of such integrated photovoltaic systems in buildings is to have the required energy at the appropriate time and place, where place is saved rather that using batteries to save energy. In this study, we present the performance of façade photovoltaic system. This analysis is based on, first the estimation of solar radiation on the buildings and secondly the characteristics of the photovoltaic module used in the system. The simulation is performed in Saad Dahleb University at Blida in Algeria, building number 13; performance was possible and reached by theoretical study and some recent mathematical models to estimate the solar radiation and the modeling of using this photovoltaic module.

Keywords: photovoltaic systems; facades; inverter; battery; stand alone; connected network; modeling, simulation.

1. Introduction

Renewable energy is a term used to describe energy that is derived from resources, like the sun and the wind; resources that are continually available to some degree or other all over the world. Sunlight is the source of most renewable energy power, either directly or indirectly. The sun can be harnessed to produce solar energy.
One of the most promising renewable energy technologies is photovoltaics. Photovoltaics (PV) is a truly elegant means of producing electricity on site, directly from the sun, without concern for energy supply or environmental harm. These solid-state devices simply make electricity out of sunlight, silently with no maintenance, no pollution, and no depletion of materials on the environnement.
A Building Integrated Photovoltaics (BIPV) system consists of integrating photovoltaics modules into the building envelope, such as the roof or the façade. By simultaneously serving as building envelope material and power generator, BIPV systems can provide savings in materials and electricity costs, reduce use of fossil fuels and emission of ozone depleting gases, and add architectural interest to the building.
While the majority of BIPV systems are interfaced with the available utility grid, BIPV may also be used in stand-alone, off-grid systems. One of the benefits of grid-tied BIPV systems is that, with a cooperative utility policy, the storage system is essentially free. It is also 100% efficient and unlimited in capacity. Both the building's owner and the utility benefit with grid-tied BIPV[1,2]. The on-site production of solar electricity is typically greatest at or near the time of a building's and the utility's peak loads. The solar

* Corresponding author. Tel.:+21325427475;
E-mail address: karasolar@yahoo.fr.

contribution reduces energy costs for the building owner while the exported solar electricity helps support the utility grid during the time of its greatest demand.
The first step in this paper is presentation of façade photovoltaic systems, the second step is photovoltaic generator modelling, and the third step is performance of façade photovoltaic systems and finally conclusion.

2. Presentation Of Façade Photovoltaic Systems

- Stand Alone: Photovoltaic power is also seeing growth in small applications, the majority of which are portable electronic goods such as calculators, watches, etc... A typical stand-alone system is shown in Figure 1.

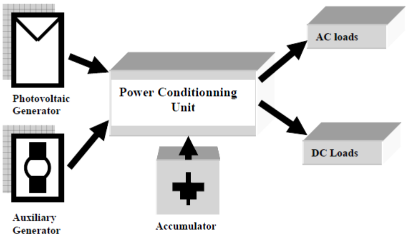

Figure 1. stand-alone photovoltaic system

- Grid connected systems: Installed grid connected systems have increased considerably over the recent years with Germany alone has reached about 1 GWp of installed PV power by the year 2004 [10]. More installations are going to be achieved as governments are putting in place more legislation to promote the use of renewable energy and the cost of PV systems continues to reduce. Integration of PV systems to utility grid network is covered in two main categories: safety and power quality[6]. With regards to safety, an important issue that has been extensively studied is the issue of islanding whereby the inverter is supposed to automatically shut down if the source of power is disconnected from the network shown in figure 2. If this does not happen the safety of the utility staff and public will be critically compromised [12].

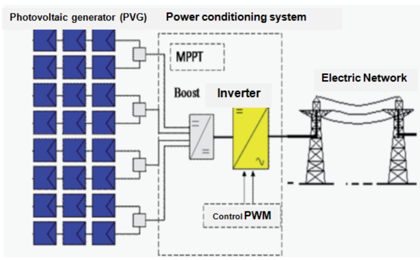

Figure 2. photovoltaic grid connected system

1.1.Component of photovoltaic system

The solar photovoltaic cells are semi conductors able to convert directly light to electricity, this conversion calls photovoltaic effect. More photovoltaic cells are connected between them to provide a tension and power; these cells are enclosed in impervious modules which preserve them from humidity and impacts. The out current and power are generally proportional at module surface. An inverter transforms the direct current product by photovoltaic panels to alternative current compatible with electric network distribution.

The battery type recommended for using in solar PV system is deep cycle battery. Deep cycle battery is specifically designed for to be discharged to low energy level and rapid recharged or cycle charged and discharged day after day for years. The battery should be large enough to store sufficient energy to operate the appliances at night and cloudy days [5].

1.2. Architectural integration of generator photovoltaic in building

Actually, the photovoltaic generator integration on building roofs and facades is considerate solution in urban environment. The different technical of architectural integration from photovoltaic modules in building are integration in roofs and facades, at first the greenhouse, the shade and the natural lighting. The different diagrams of modules integrations are elaborated by installation types and building orientation shown in figure 3.

Thus, the solar lighting loss changes by facades orientations and inclinations (figure 4)[3,4]:

- The horizontal position gives a good annual result relationship at the optimal position.
- The vertical position is less important.

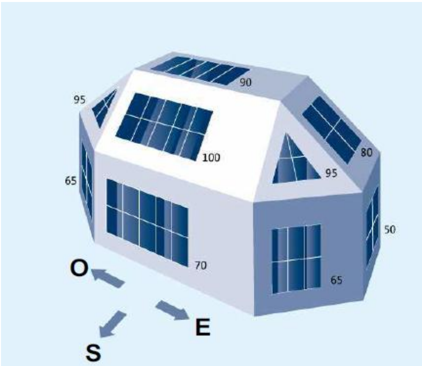

Figure 3 solar lighting distribution receive on building facades and roof by percentage [15]

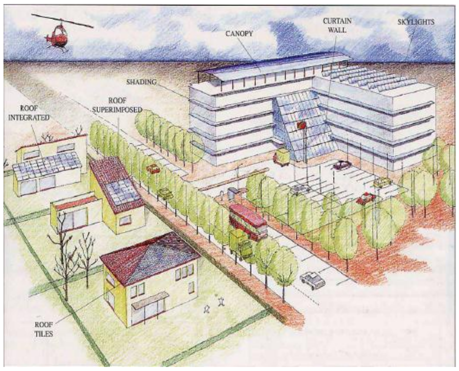

Figure 4 Different types integration in building facade

3. Photovoltaic Generator Modelling

The one diode model, which is the basic model developed in this paper, is represented as an equivalent circuit (Figure 5) including a current source whose intensity is proportional to incident radiation, in parallel with a diode and a shunt resistance Rsh. This resistance represents the leakage current to the ground. The internal losses due to current flow and the connection between cells are modeled as a small series resistance Rs. This circuit can also be redefined for a module consisting of several solar cells or for a PV array formed by the series and parallel association of several PV modules [6,9].

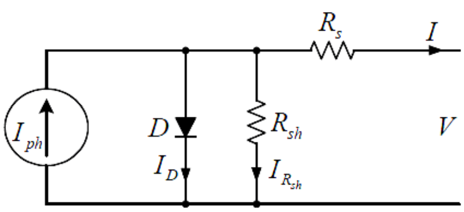

Figure 5 equivalent circuits in photovoltaic systems

The I-V characteristic is described by Equation (1), which shows the net current I of the cell as a function of the external voltage V.

$$I = I_{ph} - I_0 \left[exp\left(\frac{V + IR_s}{nV_t}\right) - 1 \right] - \frac{V + IR_s}{R_{sh}} \quad (1)$$

$$V_t = \frac{kT_j}{q} \quad (2)$$

Where Iph is the photo-generated current; k is the Boltzmann constant = $1.38x10^{-23}$ J/K; q is the electronic charge = $1.6x10^{-19}$ C; T is the cell temperature [K]; n is the ideality factor of the diode; I_0 is the saturation current due to diffusion and the saturation current due to recombination, respectively.

Equation (1) in itself do not let to draw the I-V curve that is why the temperature and irradiance dependence of the photocurrent, the knowledge of the saturation current and open circuit voltage is mandatory to complete The model. They are respectively given by [7,8,9,10].

$$I_{PH}(Tc,G) = \left(\frac{G}{G_{ref}}\right).[I_{PH_{ref}} + \mu_{ISC}.(T_c - T_{c\_ref})] \quad (3)$$

$$I_0(Tc) = I_{0\_ref}.\left(\frac{T_c}{T_{c_{ref}}}\right)^3.\exp[\left(\frac{q.E_g}{n.k}\right).\left(\frac{1}{T_{c_{ref}}} - \frac{1}{T_c}\right)] \quad (4)$$

$$V_{oc}(T_c) = V_{oc}(T_{c\_ref}) + \beta.(T_c - T_{c\_ref}) \quad (5)$$

Where:

G and Gref are respectively the incident irradiance (W/m2) and the reference irradiance (Gref=1000W/m2). Tc and Tc_ref are respectively the real and reference solar cell temperatures in degree Kelvin [K], μ_{ISC} is the Temperature coefficient for the photo generated current (or short circuit current, Isc),Eg is the energy gap in Electron Volt of the cell material, Voc is open circuit voltage[V] , β is the temperature coefficient for open circuit voltage.

The mathematical expression given by Equation (1) defines the I-V characteristics for the five-parameter model. For further accurate modeling, the energy gap has a temperature dependency too. It's given by Equation (6) [10].

$$E_g = E_{g}\text{-}_{T_{c_{ref}}}(1 - 0.0002677.(T_c - T_{c\_ref})) \quad (6)$$

Where Eg is the energy gap in Electron Volt of the cell material (Eg(Tc_ref) =1.12 for m-si).

The reference conditions Gref and Tc_ref are external conditions for witch is specified the basic data involved in the model. It can be noted that these basic data are provided by the module manufacturer or obtained by measurements procedures.

3.1. PV Generator

In practical applications several modules are gathered in a particular configuration to make what is called PV generator. In general, the configuration is made by grouping N modules in series and M modules in parallel in order to meet a certain predefined output power as shown in Figure 6 bellow. The total current fed to the load is the sum of the current of each parallel branch so that:

$$I = I_1 + I_2 + \cdots + I_M = \sum_{i=1}^{M} I_i \quad (7)$$

And the developed voltage becomes:

$$V = V_1 + V_2 + \cdots + V_N = \sum^{N} V_j \qquad (8)$$

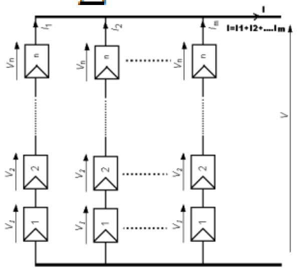

Figure 6 PV Generator configuration

Thus, the total current and voltage of the PV generator are obtained by multiplying the module current by the number of parallel branches, N, and adding the module voltage M times to obtain the whole voltage.

One of the relations which represent the module temperature dependence on the incident irradiance (G), the normal operating cell temperature (T_{NOCT}) and ambient temperature(T_a) is given by the following empirical equation.

$$T_c = T_a + G.\frac{T_{NOCT} - 20}{800} \qquad (9)$$

T_c: junction temperature.

This relation represents a good compromise between simplicity and precision where the typical dispersion of this temperature model has been found not to exceed ± 5% [13].

4.2.Calculation of errors and validation

To determine the performances of the used models, we used the criterion of the average error, MPE (Mean percentage error), the deviation of the standard error, and the criterion of the relative error, Ex . The mathematical relations of these criteria of errors are the following:

$$RMSE = \sqrt{\frac{1}{P}\sum_{i=1}^{P}(I_{mes} - I_{sim})^2} \qquad (10)$$

With:

I_{sim} Current of the simulation module, I_{mes} Current of the measurement module, P measurements numbers.

5.Performance Of Façade Photovoltaic Systems

Figure 7 presents the façade of one of bloc at Saad Dahleb University at Blida in Algeria ,the choice of this bloc is based on it's a good exposition to the sun relationship to another blocs**.**

Figure 7 South west face of bloc 13 from university

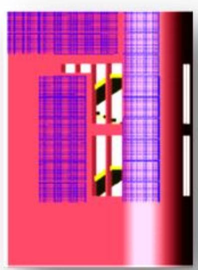

Figure 8 photovoltaic modules position on face of bloc 13 from university (draw with autocad)

5.1.Panels position on the bloc

Figure 8 presents the south west façade of the bloc with photovoltaic pannels fixed on the wall, the placement of module is relationship at the sun. This generator of 36 modules supplies a power of 3kWc, the draw of this bloc is with autocad logiciel.

5.2.Characteristic of poly crystalline module

The type of module used in our simulation is 380j buying by labset laboratory of university installing on the roof of bloc 13 of university, the electrical characteristics of this module polycrystalline silicon are presented in table 1.

characteristics	values
Voc	21,868 V
Isc	5,262 A
Rs	0,550 Ohm
Rsh	162,962 Ohm
Pmax	82,625 W
Vmp	17,398 V
Imp	4,749 A
FF	71,8 %
Efficiency, module	12,73 %
Efficiency, cell	14,69%

Table1. Electrical characteristics of silicon polycrystalline 380j module

5.3.Simulation and performance of photovoltaic systems

Figure10 in American program Nsol which presents photovoltaic generator is composed of 28 modules for a power of 2.24kWc, also the components of photovoltaic system from the south west façade of bloc 13 of Blida university. It illustrates the latitude, longitude, elevation, the inclination degree and Azimuth.

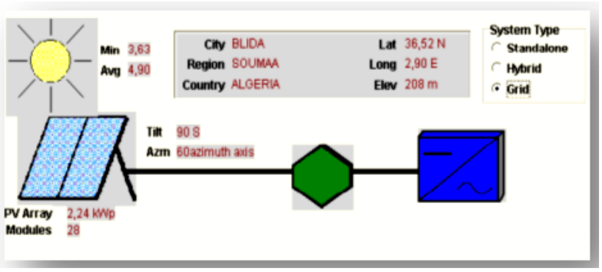

Figure 10 Simulation with Nsol for 380j poly crystalline module

We used the simulation of solar irradiation receive on the wall in azimuth function. This simulation used mathematicals models which permit to calculate the solar irradiation on an inclined plan. The simulation calculated the variation of solar irradiation in function of hour's day with different facades orientation in Soumaa region at Blida city in Algeria. The figure 11 shows day irradiation on horizontal surface compared to a wall with different orientation which are east (90,-90), south east(90,-45), south(90,0), south west(90,45) and west(90,90), the first number between brackets presents the inclination angle , the second number presents the orientation of vertical wall relationship at the four cardinals points(north, south, east and west). The results show that the vertical surface receives the maximal of solar irradiation in winter season. This situation comes back to low elevation of sun in winter which permits at a wall to receive a high solar irradiation in summer where the solar elevation is highest.

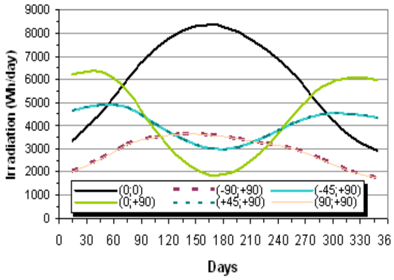

Figure 11 day irradiation in azimuth fonction

The figure 12 presents winter season (fifteenth of January), where irradiation obtains its maximal for a negative Azimuth before mid-day, for positive Azimuth the irradiation is maximal in afternoon, for null Azimuth the irradiation is maximal between 12 and 14 hours and with inclination 90º, the irradiation is superior relationship the inclination 0º.

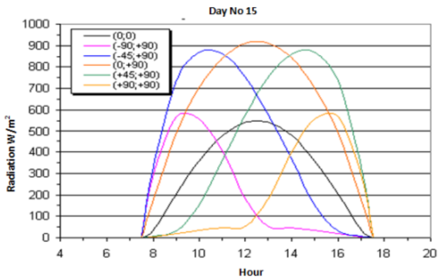

Figure 12 Irradiation vs = azimuth (days 15)

The figure 13 presents the spring irradiation, obtains its maximal for a negative azimuth before mid-day, for a positive Azimuth the irradiation is maximal in the afternoon, for a null azimuth the irradiation is maximal between 12 and 14, for an inclination 90º the irradiation is nearly equal to inclination 0 º.

In summer, as per Figure 14, the irradiation obtains its maximal for a negative Azimuth before mid-day, for a positive Azimuth the irradiation is maximal in the afternoon, for null Azimuth the irradiation is maximal between 12 and 14 hours, for inclination 90º the irradiation is inferior relationship the inclination 0º.

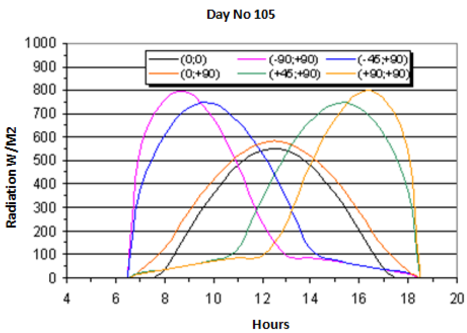

Figure 13 Irradiation vs = azimuth (days 105)

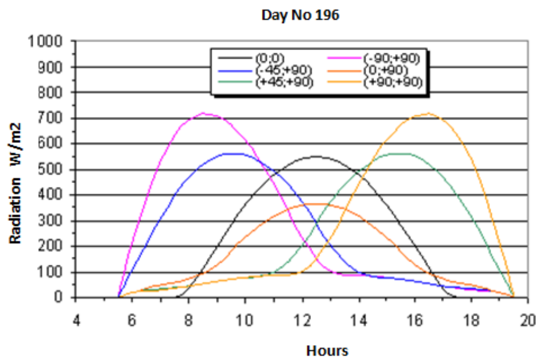

Figure 14 Irradiation vs = azimuth (days 196)

In autumn, as per figure 15. the irradiation obtains its maximal for a negative Azimuth before mid-day, for a positive Azimuth the irradiation is maximal in the afternoon, for null Azimuth the irradiation is maximal between 12 and 14 hours, for inclination 90º the irradiation is superior relationship the inclination 0º.

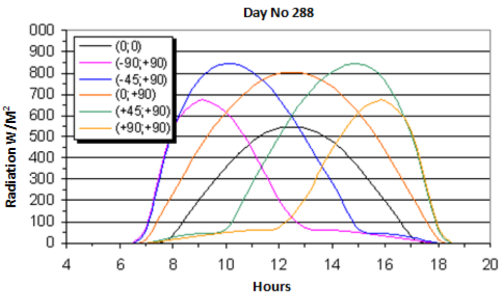

Figure 15 Irradiation vs = azimuth (days 288)

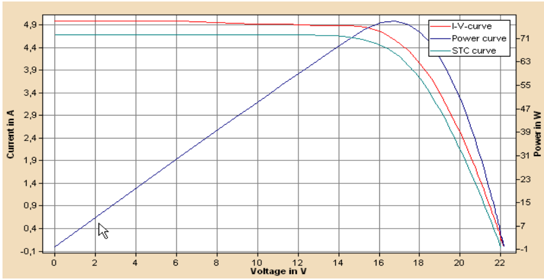

Figure 16 Matlab Measured and simulated I(V) curves of polycrystalline silicone panels 380j

The I-V/P-V characteristics and all precedent figures of irradiation are measured with versus simulated ones by Matlab & Simulink program, which is obtained by introducing the calculated five parameters, are given in Figure 16 bellow. The STC parameters obtained by the translation procedure and the reference parameters obtained by applying the analytical method are both given in Table 1, the desired PV generator operating point is the maximum power point (MPP), presented here in the P-V characteristic from July fourteenth at 12:00 hour.

6. Conclusion

World energy consumption comes primarily from the depleted fossils (oil, coal, natural gas, etc) of which the massive use can lead to the exhaustion as of these resources and threatens really the environment by the emissions of polluting gas and with greenhouse effect. The photovoltaic solar energy utilization as electric energy source is a solution adopted well to reduce the emissions of these harmful gases for the environment. This paper is related to the study of the simulation of the performances of the BIPV. These systems, which use the integration of the photovoltaic generator in the building, are an option in full growth in the Western countries because this technology makes it possible to bring the production closer to electrical energy at the strong place of its consumption. This energy source is durable and these components are modular and flexible. From the aesthetic point of view, the photovoltaic generator can replace several components of construction easily, energy of the front glazed with the tight roofs. The contributions of this paper in the field of the BIPV systems are summarized as follows:

- Presentation of various techniques of architectural integration of the photovoltaic generator in the building.
- Validation, using the data measured on site, of the recent digital models which consider the component direct and diffuse of the irradiation solar on the levels horizontal and inclined.
- Development of a program which makes it possible to calculate the solar irradiation on the various Faces of a potential building for the architectural integration of the photovoltaic generator.

We hope that the results of this work will contribute significantly in the comprehension of these photovoltaic systems of frontage and in decision making so that a photovoltaic installation of this type is a reality in our University Saad Dahleb de Blida.

References

[1] T. Markvart and L. Castanier: Practical Handbook of Photovoltaics: Fundamentals and Applications. Edition Elsevier. 2003.

[2] M. Iqbal: An introduction to solar irradiation. Academic Press. Toronto. pp.303, 1983.

[3] Analyse de projets d'installation photovoltaïque, édité par le Ministre de Ressources naturelles du Canada, ISBN : 0-662-75477-8, 2001.2004.

[4] T.M. Klucher: Evaluation of models to predict insolation on tilted surfaces. Solar Energy, Vol. 23(2), pp. 111-114, 1979.

[5] M. Collares-Pereira and A. Rabl: The average distribution of solar radiation – correlations between diffuse and hemispherical and between daily and hourly insolation values. Solar Energy, Vol. 22, pp.155-164, 1979.

[6] J. A. Duffie, W. A. BeckmanA:" Solar Engineering of Thermal Processes.". New York: John Wiley & Sons, Inc., 1991.

[7] L. Castaner and S. Silvestre: "Modelling Photovoltaic Systems using Pspice." John Willey & Sons, LTD, (2002).

[8] Kerr MJ, Cuevas A: "Generalized analysis of the illumination intensity vs. open-circuit voltage of PV modules". Sol Energy 2003;76:263–7.

[9] T. U. Townend: "A method for estimating the long-term performance of direct-coupled photovoltaic system", M.S. Thesis, Unv. Of Wisconsin-Madison (1989).

[10] W. De Soto: "Improvement and validation of a model for photovoltaic array performance", M.S Thesis, Solar energy laboratory, Univ. Wisconsin-Madison (2004).

[11] P. Spirito and V. Abergamo: « Reverse Bias power dissipation of shadowed or faulty cells in different array configuration.", Proc. of the Fourth European Photovoltaic solar Energy Conference, 1982, pp. 296-300.

[12] C. F. Lopez Penida: "Experimental evaluation of reverse bias stress induced on photovoltaic modules for different configurations", Solid Wind Techn. 3. (1986), pp. 85-88.

[13] M. A. Abella, M.C Alonso, K. Mukadem, F. Chenlo: "Validation of theoretical models in big size PV plants". 14th EPSEC, Barcelona, Spain 1997.