IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE)
e-ISSN: 2278-1676,p-ISSN: 2320-3331, Volume 11, Issue 3 Ver. IV (May. – Jun. 2016), PP 112-121
www.iosrjournals.org

Simulation and comparative study of different PV Modules technologies of silicon (Monocrystalline, polycrystalline and Amorphous) in Beni Mellal

M.Adar[1], H. Bazine[1], A .Abounada[1] And M.Mabrouki[1]
Laboratoire de Génie Industriel, Département de Physique Faculté des Sciences et Techniques, Université Sultan Moulay Slimane, BP 523 Beni Melall, MAROC.

Abstract: *This work deals with, firstly, the estimation of the optimal production photovoltaic mini plants of 2KW for each one using three types of silicon technologies that are well known: monocrystalline, poly crystalline and amorphous silicon, in the region of Beni Melall, we used for that the software PVGIS, Tecsol.fr and Solargis. Secondly, a comparative study between the estimated and experimental results is done.*
Keywords: *renewable-energy, solar-energy, power production, photovoltaic, mono-crystalline, poly-crystalline, amorphous, simulation, PVGIS, Simulink,Tecsol.fr, Solargis*

I. INTRODUCTION

Recently, energy generated from clean, efficient, and environmentally friendly sources has become one of the major challenges for engineers and scientists [1]. The increase of the cost of fossil energies on the one hand and the limitation of their resources on the other hand and result in the photovoltaic energy becoming more and more a solution among the promising energy options.

Morocco has a strong solar potential especially South and South-east. Generally, Morocco benefits plenty of sunshine and solar potential is far from to be fully exploited. This will leads to think that the growth of solar energy will keep going even intensify if the necessary structures are in place. The potential of solar energy in Morocco is immeasurable. Although it has not oil or gas, and imports 96% of its energy needs, a colossal bill 98 DH billion (figures from 2012), Morocco has eleven hours a day and light a heat preservation for seven hours. This represents more than 5 kWh / m²/d average and more than 3000 hours of sunshine per year [2].

With the national solar program that provides for the installation of plants superpowers 5 sites for a total output of 2,000 MW in 2020, Morocco will save up to one million tons of oil equivalent, or more than 4 billion dirhams and avoid the emission of 3.7 million tons of CO 2 per year. The Morocco will also be with this solar program the ability to market abroad 20% of its electricity renewable [2].

This work is in this context it is to estimate the electrical energy produced by a photovoltaic installation (grid-connected) on the roof of the Faculty of Science and Technology Beni Mellal city, depending on weather conditions in this city.

II. SITE AND SYSTEM INFORMATION

II.1.Site Description

Coordinates: 32° 22' 35.73" N, 06° 19' 7.72" W
Elevation a.s.l.: 526 m
Slope inclination: 1°
Slope azimuth: 289° west
Annual global in-plane irradiation: 2177 kWh/m2
Annual air temperature at 2 m: 18.6 °C

II.2.Geographic position

Fig1: Geographic position of the site [3]

II.3.PV system information

Installed power: 3x2kWp

Type of modules: - Monocrystalline silicon (m-Si): 8 panels
- Polycrystalline silicon (p-Si): 8 panels
- Amorphous silicon (a-Si): 12 panels

Mounting system: fixed mounting, roof installed

Azimuth/inclination: 180° (south) / 30°

II.4.Terrain horizon and day length

Fig.2: Path of the Sun over a year [3] Path of the Sun over a year. Terrain horizon (drawn by grey filling) and module horizon (blue filling) may have shading effect on solar radiation. Black dots show True Solar Time. Blue labels show Local Clock Time [3].

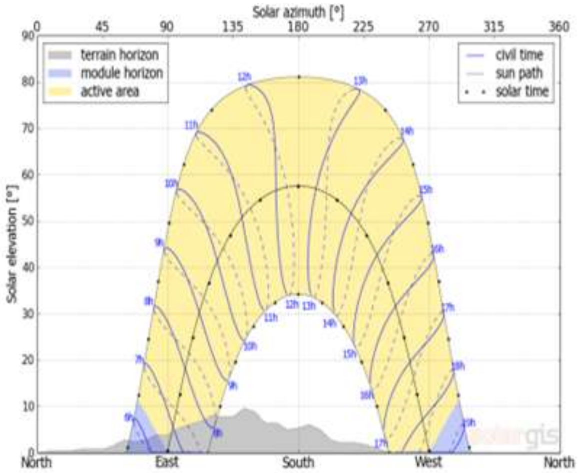

Fig.2: Path of the Sun over a year [3]

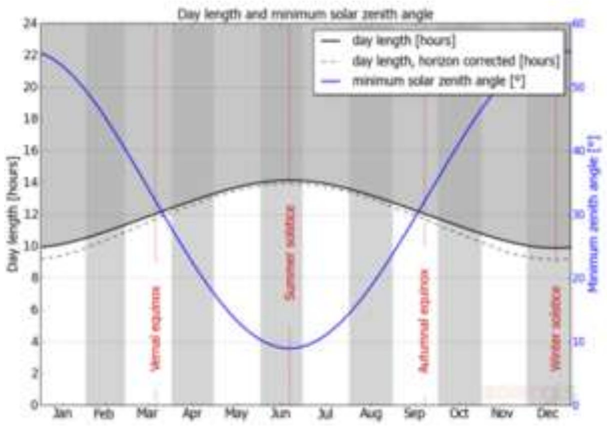

Fig.3: Change of the day length during a year [3]

Change of the day length and solar zenith angle during a year. The local day length (time when the Sun is above the horizon) is shorter compared to the astronomical day length, if obstructed by higher terrain horizon.[3]

III. SIMULATION

The objectives of the simulation of PV system can be summarized in providing an estimate of energy production and distribution in time, in addition to quantifying the disruptive effects in order to identify weaknesses and optimize the entire installation.

For our case, we use the Tecsol.fr, the PVGIS, the Simulink (MATLAB) and SOLARGIS (pvPlanner) as our tools for simulating the functioning of the three PV technologies. The three PV technologies are the monocrystalline, polycrystalline and amorphous; with 2kWP for each technology to be installed at FST in Beni Mellal.

While running the simulation the first step is to introduce the input data about the geographical location of the installation. These include the PV site longitude and latitude. The software has its own radiation and temperature database about the chosen sites, which it uses for its analysis. Finally, complete content and organizational editing before formatting. Please take note of the following items when proofreading spelling and grammar:

III.1. Simulation with PVGIS software

In this paper, we have simulated the production of photovoltaic electricity using three mini-plants connected to the grid in Beni Mellal, with PVGIS Software. The three units are each equipped with a different silicon technology: monocrystalline, polycrystalline, and amorphous, and each plant has a power of 2kWp. The goal of our work is to determine which plant and inclination angle gives the optimal productivity.

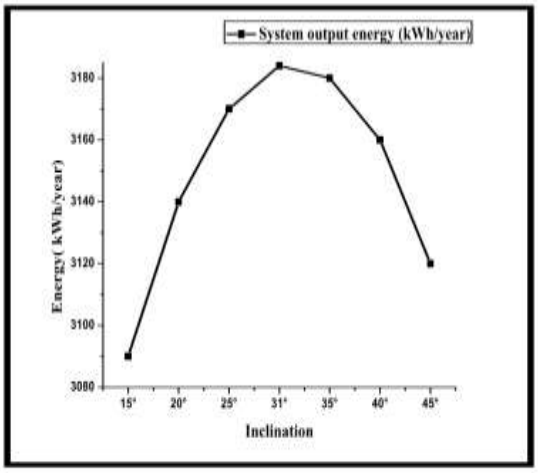

Fig.4: Optimal inclination angle

Table I Annual Irradiation For Beni Mellal

Month	Hh	Hopt	H(30)	Iopt
Jan	3360	5120	5120	58
Feb	4160	5610	5610	49
Mar	5540	6470	6470	36
Apr	6170	6400	6400	20
May	6860	6450	6450	6
Jun	7710	6930	6930	0
Jul	7710	7090	7090	3
Aug	6960	6970	6970	15
Sep	5730	6460	6460	31
Oct	4740	6070	6070	45
Nov	3500	5110	5110	55
Dec	3070	4830	4830	60
Year	5470	6130	6130	30

Hh: Irradiation on horizontal plane (Wh/m2/day)
Hopt: Irradiation on optimally inclined plane (Wh/m2/day)
H(30): Irradiation on plane at angle: 30deg. (Wh/m2/day)
Iopt: Optimal inclination (deg.)

The maximum solar irradiation on a horizontal plane and an inclined plane is given for inclination 30° on Fig.4 and TABLE.I. For the tilted plane, the radiation ranges between 5.110 and 7.090 kWh/m^2/day. However, for the horizontal one is more irregular over the year between 3.070 and 7.710 kWh/m2/day

Table II Estimation of Solar Electricity Generation

	Fixed system : inclination = 30° Orientation = 0°			
Month	Ed	Em	Hd	Hm
Jan	3.94	122	5.12	159
Feb	4.26	119	5.61	157
Mar	4.73	147	6.47	201
Apr	4.65	140	6.40	192
May	4.62	143	6.45	200

Jun	4.86	146	6.93	208
Jul	4.88	151	7.09	220
Aug	4.79	149	6.97	216
Sep	4.58	137	6.46	194
Oct	4.43	137	6.07	188
Nov	3.88	116	5.11	153
Dec	3.75	116	4.83	150
Year	4.45	135	6.13	186
Total for year		1620		2240

Ed: Average daily electricity production from the given system (kWh).
Em: Average monthly electricity production from the given system (kWh).
Hd: Average daily sum of global irradiation per square meter received by the modules of the given system (kWh/m2).
Hm: Average sum of global irradiation per square meter received by the modules of the given system (kWh/m2).

The data base of PVGIS includes only the crystalline silicon.
Our system, according to TABLE II, produces more electricity in July with an average of 151 KWh and less power in December with a mean of 116 KWh.
To make a comparison between the three silicon technologies, we will make the simulation of our station on the site Tecsol.fr.

III.2. Simulation with Tecsol.fr

We introduced on the site Tecsol.fr the number of photovoltaic panels and their power and the peak power of each mini station

III.2.1. Monocrystalline silicon (m-Si)

Table III The Electricity Generated By The Station Monocrystalline Silicon [4]

Month	**Solar Energy received by a horizontal plane (Wh/m2.day)**	**Solar Energy received by a plane of sensors (Wh/m2.day)**	**Electricity produced (KWh/Month)**
Jan	3270	4948	235
Feb	4040	5388	231
Mar	4990	5770	274
Apr	5860	5978	274
May	6690	6273	298
Jun	7470	6641	305
Jul	7800	7010	332
Aug	7210	7081	336
Sep	5980	6689	307
Oct	4660	5991	284
Nov	3520	5150	236
Dec	3000	4677	222
Total energy (KWh/year)			3334
Total CO2 prevented (Kg/year)			1200
Productivity (KWh/KWp.year)			1634

III.2.2. Polycrystalline silicon (p-si):

Table IV The Electricity Generated By The Station Poly-Crystalline Silicon [4]

Month	**Solar Energy received by a horizontal plane (Wh/m2.day)**	**Solar Energy received by a plane of sensors (Wh/m2.day)**	**Electricity produced (KWh/Month)**
Jan	3270	4948	235
Feb	4040	5388	229
Mar	4990	5770	272
Apr	5860	5978	273
May	6690	6273	296
Jun	7470	6641	303
Jul	7800	7010	330
Aug	7210	7081	334
Sep	5980	6689	305
Oct	4660	5991	282
Nov	3520	5150	235
Dec	3000	4677	220
Total energy (KWh/year)			3312
Total CO2 prevented (Kg/year)			1192
Productivity (KWh/KWp.year)			1656

III.2.3. Amorphous Silicon (a-Si)

Table V The Electricity Generated By The Station Amorphous Silicon [4]

Month	Solar Energy received by a horizontal plane (Wh/m2.day)	Solar Energy received by a plane of sensors (Wh/m2.day)	Electricity produced (KWh/Month)
Jan	3270	4948	212
Feb	4040	5388	210
Mar	4990	5770	250
Apr	5860	5978	250
May	6690	6273	271
Jun	7470	6641	278
Jul	7800	7010	303
Aug	7210	7081	306
Sep	5980	6689	280
Oct	4660	5991	259
Nov	3520	5150	216
Dec	3000	4677	202
Total energy (KWh/year)			3039
Total CO2 prevented (Kg/year)			1094
Productivity (KWh/KWp.year)			1634

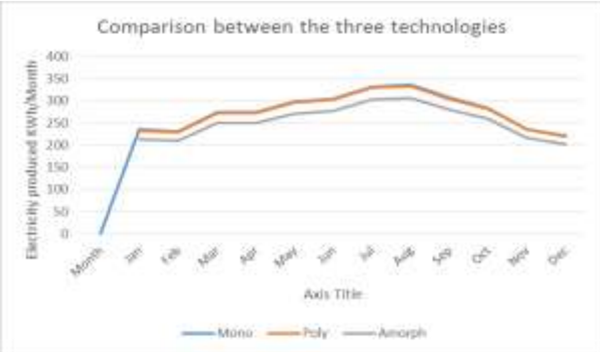

Fig.5: Comparison between the three technologies

Unlike PVGIS which provides high output in July, Tecsol.fr provides a high production in the month of August on top of that it provides that the monocrystalline silicon station gives the best production. To ensure these results we redid the simulation on Solargis (pvPlanner).

III.3. Simulation with Solargis (pvPlanner):

III.3.1. Crystalline silicon (c-Si):

Table VI Annual Pv Electricity Production [3]

Month	Esm	Esd	Etm	Eshare	PR
Jan	125	4.04	251	7.6	79.6
Feb	123	4.38	245	7.4	78.6
Mar	147	4.74	294	8.9	76.9
Apr	147	4.91	294	8.9	76.2
May	148	4.78	297	9.0	74.7
Jun	150	4.99	300	9.0	72.9
Jul	150	4.85	300	9.1	71.4
Aug	151	4.86	302	9.1	71.6
Sep	141	4.70	282	8.5	73.7
Oct	136	4.37	271	8.2	75.9
Nov	123	4.09	245	7.4	78.1
Dec	116	3.75	232	7.0	79.8
Year	1657	4.54	3313	100.0	75.5

Long-term monthly averages:
Es_m : Monthly sum of specific electricity prod. [kWh/kWp]
Es_d : Daily sum of specific electricity prod. [kWh/kWp]
Et_m : Monthly sum of total electricity prod. [kWh]
E_{share} : Percentual share of monthly electricity prod. [%]
PR Performance ratio [%]

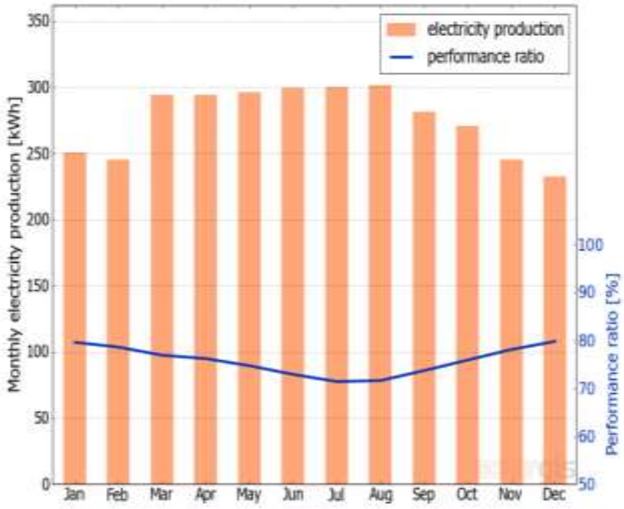

Fig.6 Diagram of annual PV electricity production [3]

1) Amorphous silicon (a-Si)

II. **Table VII** Annual Pv Electricity Production [3]

Month	Esm	Esd	Etm	Eshare	PR
Jan	131	4.22	262	7.2	83.1
Feb	130	4.65	261	7.1	83.6
Mar	160	5.15	319	8.7	83.5
Apr	161	5.38	323	8.8	83.6
May	166	5.35	331	9.1	83.5
Jun	171	5.69	342	9.3	83.1
Jul	174	5.61	348	9.5	82.6
Aug	175	5.63	349	9.5	82.8
Sep	160	5.32	319	8.7	83.5
Oct	150	4.83	299	8.2	83.9
Nov	131	4.36	262	7.2	83.3
Dec	121	3.90	242	6.6	83.0
Year	1828	5.01	3656	100.0	83.3

Es_m : Monthly sum of specific electricity prod. [kWh/kWp]
Es_d : Daily sum of specific electricity prod. [kWh/kWp]
Et_m : Monthly sum of total electricity prod. [kWh]
E_{share} : Percent share of monthly electricity prod. [%]
PR Performance ratio [%]

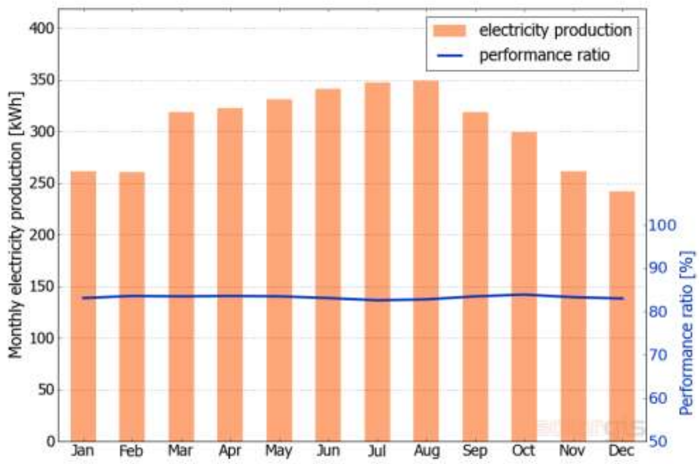

Fig.7 Diagram of annual PV electricity production [3]

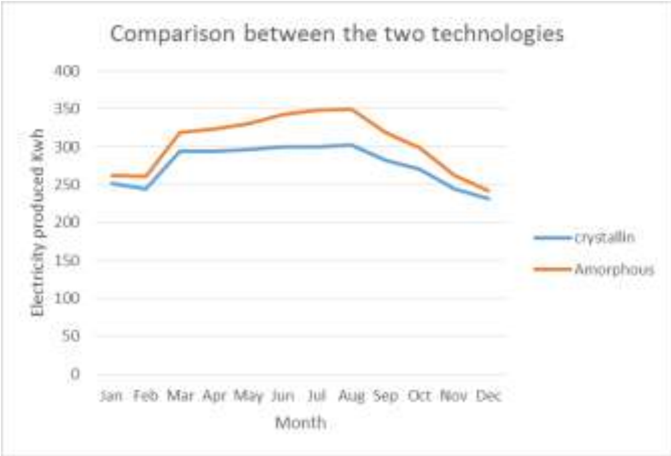

Fig.8 Comparison between two technologies

Solargis provides the same production for the months of July and August in addition it provides that the amorphous silicon-based station will give the best production.

III.4. Modeling photovoltaic system

1) Model of Photovoltaic cell :

The electrical equivalent of our system allows us to find the photovoltaic generator model. Many mathematical models have been developed to represent their highly nonlinear behavior resulting from semiconductor junctions. It describes PV modules accurately with temperature and solar irradiance dependency [5]. The main advantage of using the electrical circuit model is the availability of the standard electrical software such as MATLAB where the PV model can be seamlessly, integrated into a larger PV systems comprising of power converter, grid connectivity, etc. There are other modeling techniques that do not utilize the equivalent circuit [6,7], but they are not adopted by PV simulators.

The equivalent electrical installation is as follows:

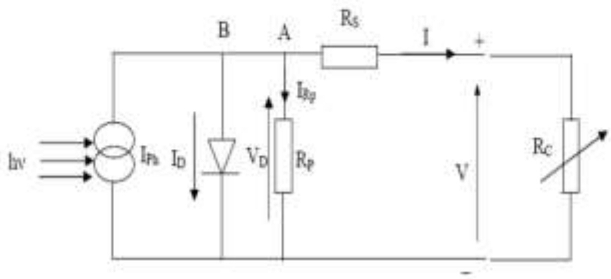

Fig.9 The equivalent circuit of PV cell

Apply the law of Kirchhoff to the nodes A, B:

$I=I_{ph}-I_D-I_{Rp}$ (I)

The current I supplied by the cell is the algebraic sum of three current:

I_{Ph}: independent photocurrent in V (or R_S) is proportional to the incident flux (rate of generation- recombination) and the holder's diffusion lengths:

$I = qg\,(Ln + Lp)$ (II)

I_{Rp} : current through R_P.

$I_{Rp} = V_D/R_P = (V + R_S I)/R_P$ (III)

$V_D = R_P\, I_{Rp} = V + R_S I$ (IV)

I_D: current diode

$I_D = Io(e^{qVD/AKT}-1)$ (V)

Substituting in (I) the equations (II), (III),(IV) and (V), the characteristic equation becomes:

$I=I_{ph}- Io(e^{\left(\frac{qV}{AKT}\right)(V + RSI)} -1) - (V + R_S I)/R_P$ (VI) [8]

2) Solar photovoltaic module/array

PV cells are grouped together in larger units known as PV modules or arrays, which are combined in series and parallel to provide the desired output voltage and current.

The well-known equivalent circuit of solar cells arranged in N_P -parallel and N_S -series is shown in Figure

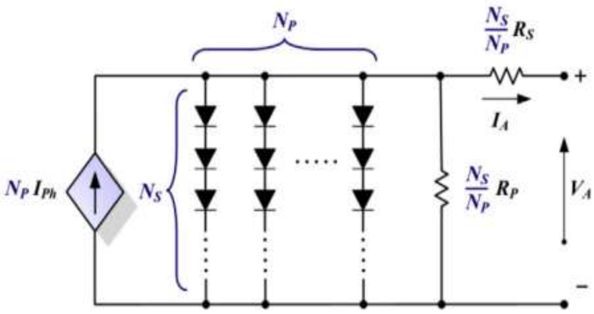

Fig.10 The equivalent circuit of the PV pannel

The mathematical model that predicts the power production of the PV generator becomes an algebraically simply model, being the currente voltage relationship defined in Eq:VII

$$I_A = N_P I_{ph} - N_P I_{RS}\left\{\exp\left[\frac{q}{AKTc}\left(\frac{VA}{Ns}+\frac{IARs}{NP}\right)\right]-1\right\} - -\frac{Np}{Rp}\left(\frac{VA}{Ns}+\frac{IARs}{Np}\right) \quad \text{(VII)}$$

where:
I_A : PV array output current
V_A : PV array output voltage
I_{Ph} : Solar cell photocurrent
I_{RS} : Solar cell reverse saturation current (aka dark current)
q: Electron charge, 1.60217733ee19 Cb
A: P-N junction ideality factor, between 1 and 5
k: Boltzmann's constant, 1.380658ee23 J/K
T_C : Solar cell absolute operating temperature, K
R_S : Cell intrinsic series resistance
R_P : Cell intrinsic shunt or parallel resistance

1) Simulation on Simulink:

The block diagram in Simulink equivalent to monocrystalline photovoltaic field is:

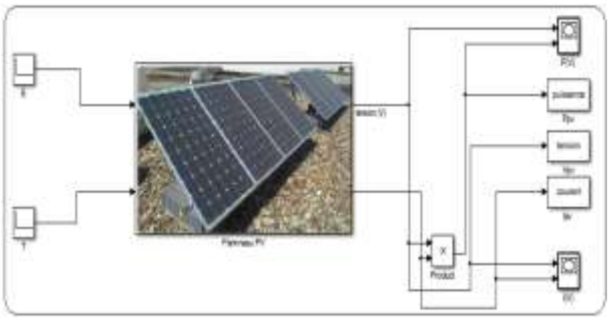

Fig.11 The block diagram of the PV station

The temperature and irradiation data are given by Retscreen.
Compiling the program gives the following results:

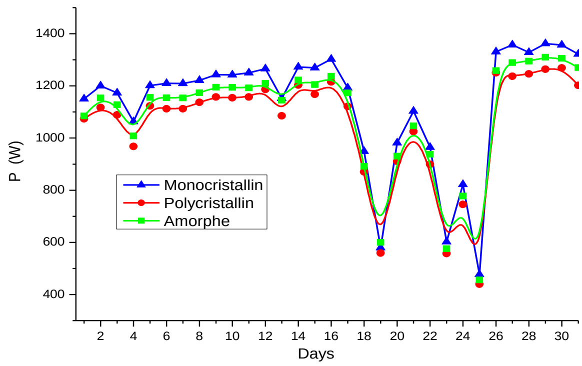

Fig.12 Comparison of the powers of the month March

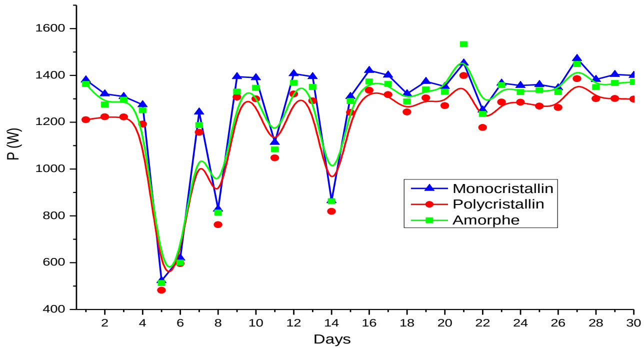

Fig.13 Comparison of the powers of the month April

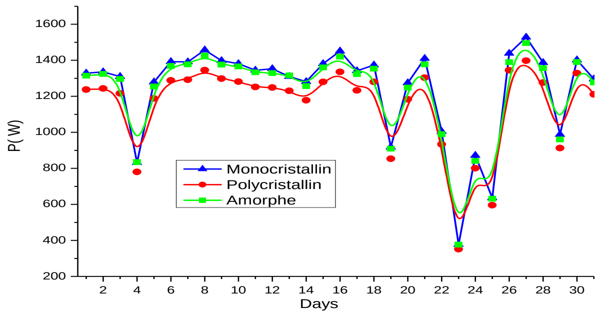

Fig.14 Comparison of the powers of the month May

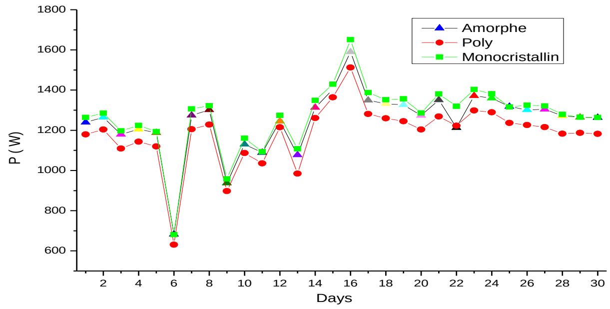

Fig.15 Comparison of the powers of the month June

The simulation results show that the mono-crystalline product more of electricity than the other silicon technologies in weather conditions of Beni Mellal.

III. COMPARATIVE ANALYSIS

We will make a comparison between the different results given by the simulation and experimental data. Unfortunately, we have just that data for March, April and May.

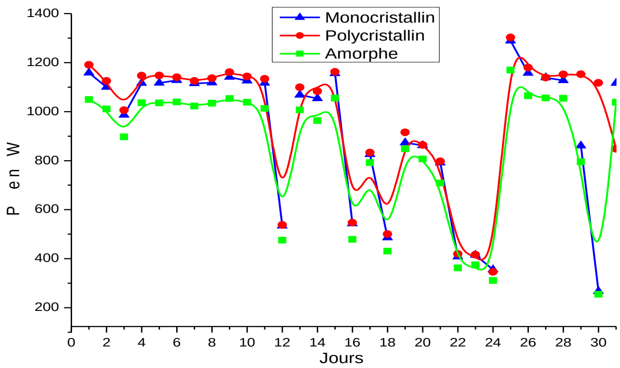

Fig.16 Comparison of powers for the month March

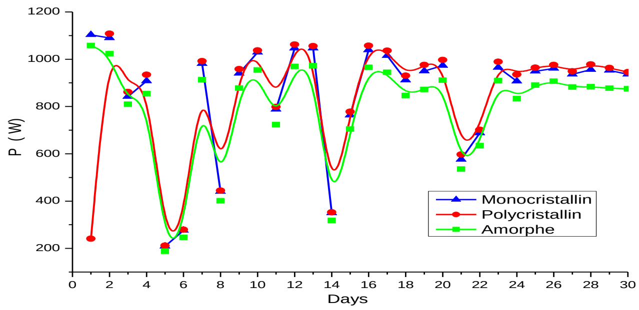

Fig.17 Comparison of powers for the month April

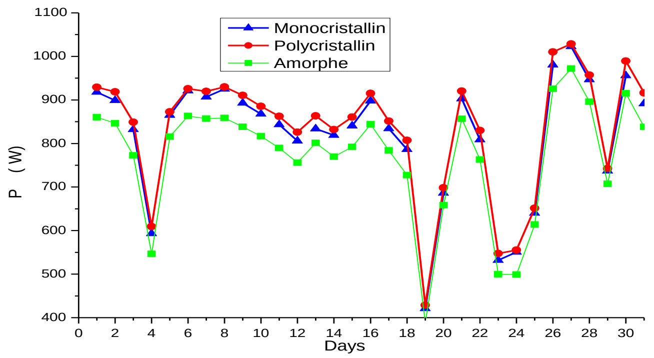

Fig.18 Comparison of powers for the month May

The experimental data of three months of March, April and May show that the polycrystalline gives the best production and the amorphous product more than the polycrystalline.

IV. CONCLUSION

We have given the climate data for the case of Beni Mellal site, the optimal values are obtained for a 30° inclination and a full. The investigation of the annual productivity shows that [4]:

• A PV system (Si-mono-c, Surface 13.30 m²) connected to the nominal power network 2.04 KWp delivers an energy of 3334 kWh per year.

• A PV (Si-poly-c, Surface 13.01 m²) connected to the nominal power network 2 KWp delivers an energy of 3312 KWh per year.

• A PV system (Si-amorphous surface of 15.39 m²) connected to the nominal power network 1.86 kWp delivers an energy of 3039 KWh year.

The experimental data show that the polycrystalline gives the best production in March, April and May. The difference between the measured and simulated data is due to lack of temperature and the instantaneous irradiance data and the effects of dust and shade does not taken into account also the databases of the Software used don't contain the SOLAR WORLD products.

Acknowledgements:

We thank IRESN institute (Morocco) for their financial support to Proprema project.

REFERENCES

[1] R.-J.Wai, W.-H. Wang, and C.-Y. Lin, "High-performance stand-alone Photovoltaic generation system," IEEE Trans. Ind. Electron., vol. 55, no. 1, pp. 240–250, Jan. 2008.

[2] www.futura-sciences.com/.../energie-renouvelable-potentiel-energetique.

[3] www.solargis.info.

[4] www.tecsol.fr

[5] F. Bouchafaa, I. Hamzaoui and A. Hadjammar, 'Fuzzy Logic Control for the Tracking of Maximum Power Point of a PV System', Energy Procedia, 6, pp. 633 - 642, 2011.

[6] Marion B, Rummel S, Anderberg A. Current–voltage curve translation by bilinear interpolation. Prog Photovolt: Res Appl; 12:593–607, 2004.

[7] Hishikawa Y, Imura Y, Oshiro T. Irradiance-dependence and translation of the I–V characteristics of crystalline silicon solar cells. In: Conference record of the twenty-eighth on photovoltaic specialist's conference,. IEEE; 2000. p.1464–7 2000.

[8] M. Mabrouki physica status solidi (a) 191(1):345-354 2002·