Grid connected PV System design and Feasibility Study for the Electrical and Electronics Engineering Department of University of Tripoli Using PV*SOL Software

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ABSTRACT

The solar energy is considered one of the most important renewable energy resources and the most pure and friendly to the environment. The world is gradually moving towards sustainable renewable energy sources due to diminishing fossil fuel energy resources and increasing demand for power. The electricity supply in Libya is instable, especially in the capital and other large cities. Users such as residential, commercial and universities are looking for alternative sources to deliver adequate standards of electricity. The photovoltaic technique is constantly developing in many ways as it generates electricity without risks or extra costs. There is significant potential for the use of the photovoltaic solar energy in countries like Libya which receive abundant amounts of solar radiation around the year. In this paper the measurements have been taken to the drawing current for each phase during 24 hours for 15 days and recording the average of each result, the power consumption of the building have been calculated for several months considering that consumption during this period is mostly constant. A solar PV system was designed for the electrical & electronic engineering department building and its performance has been simulated using PV*SOL software. Critical parameters such as Power at maximum power point and capacity factor have been calculated for the designed PV system. Financial Analysis was then conducted to check the economic feasibility of the proposed solar PV systems. Environmental impact has also been studied. The simulation results and analysis of the system are presented in the paper.

Keywords: Renewable Energy, Photovoltaic technique, Power at maximum power point, capacity factor PV*SOL software

1. Introduction

Solar cells, also called photovoltaic (PV) cells by scientists, convert sunlight directly into electricity. PV gets its name from the process of converting light (photons) to electricity (voltage), which is called the PV effect. The PV effect was discovered in 1954, when scientists at Bell Telephone discovered that silicon (an element found in sand) created an electric charge when exposed to sunlight. Soon solar cells were being used to power space satellites and smaller items like calculators and watches. [2] PV devices can be used to power anything from small electronics such as calculators and road signs up to homes and large commercial businesses. Solar PV experienced another year of record growth in 2015, with the annual market for new capacity up 25% over 2014. More than 50 GW was added – equivalent to an esti-mated 185 million solar panels – bringing total global capacity to about 227 GW. The annual market was nearly 10 times the size of cumulative world capacity just a decade earlier. Although the top three markets in 2015 were responsible for the majority of capacity added, globalization continued with new markets on all continents. [5] Solar energy is energy supplied by nature it is thus free and abundant. PV panels provide clean – green energy. During electricity generation with PV panels there is no harmful greenhouse gas emissions thus solar PV is environmentally friendly. Solar energy is especially appropriate for smart energy networks with distributed power generation. Solar Panels cost is currently on a fast reducing track and is expected to continue reducing for the next years – consequently solar PV panels has indeed a highly promising future both for economical viability and environmental sustainability. Operating and maintenance costs for PV panels are considered to be low, almost negligible, compared to costs of other renewable energy systems. Residential solar panels are easy to install on rooftops or on the ground without any interference to residential lifestyle. Solar energy panels require additional equipment (inverters) to convert direct electricity (DC) to alternating electricity (AC) in order to be used on the power network. For a continuous supply of electric power, especially for on-grid connections, Photovoltaic panels require not only Inverters but also storage batteries; thus in-creasing the investment cost for PV panels considerably. In case of land-mounted PV panel installations, they require relatively large areas for deployment; usually the land space is committed for this purpose for a period of 15-20 years or even longer. Photovoltaic cells are connected electrically in series and/or parallel circuits to pro-duce higher voltages, currents and power levels. Photovoltaic modules consist of PV cell circuits sealed in an environmentally protective laminate, and are the fundamental building blocks of PV systems. Photovoltaic panels include one or more PV modules assembled as a pre-wired, field-installable unit. A photovoltaic array is the complete power-generating unit, consisting of any number of PV modules and panels. A good design involves accurate knowledge of daily electrical load calculation and accounts for all worst-case scenarios, which might possibly occur during operation. A good designer will be pragmatic and keep the costs down by cutting on unnecessary over sizing the system. [1]

2. Evaluate the Annual Consumption Data for a Building:

The Electrical and Electronic department is located inside University of Tripoli, nearby Faculty of

Engineering. Most of the electrical loads used in the building are for lights and air-conditioners. When a photovoltaic system is designed, it is important to be able to evaluate the consumption of users with respect to the production of the system. In particular, it is necessary to quantify the self-consumption. Measurements have been done to the drawing current for each phase during 24 hours for 15 days and recording the average of each result. The power consumption of the building has been calculated for several months, considering that consumption during this period is mostly constant. The daily consumption of the building when the air-conditioners are turned off is presented in table 1 and table 2 shows the daily consumption of the building when the air-conditioners are turned on.

Table 1 Measured Average Consumption Data for two weeks air-conditioners are turned off.

Time (H)	Phase A (Amp)	Phase B (Amp)	Phase C (Amp)	Power of Phase A (W)	Power of Phase B (W)	Power of Phase C (W)	Total Power (W)
0	25	68	59	4950	13464	11682	30096
1	25	68	59	4950	13464	11682	30096
2	25	68	59	4950	13464	11682	30096
3	25	68	59	4950	13464	11682	30096
4	25	68	59	4950	13464	11682	30096
5	25	68	59	4950	13464	11682	30096
6	25	68	59	4950	13464	11682	30096
7	26	68	59	5148	13464	11682	30294
8	32	98	68	6336	19404	13464	39204
9	60	93	73	11880	18414	14454	44748
10	60	117	68	11880	23166	13464	48510
11	60	130	73	11880	25740	14454	52074
12	62	130	72	12276	25740	14256	52272
13	60	131	70	11880	25938	13860	51678
14	45	136	73	8910	26928	14454	50292
15	39	128	76	7722	25344	15048	48114
16	39	112	72	7722	22176	14256	44154
17	25	68	59	4950	13464	11682	30096
18	25	68	59	4950	13464	11682	30096
19	25	68	59	4950	13464	11682	30096
20	25	68	59	4950	13464	11682	30096
21	25	68	59	4950	13464	11682	30096
22	25	68	59	4950	13464	11682	30096
23	25	68	59	4950	13464	11682	30096

Table 2 Measured Average Consumption Data for two weeks air-conditioners are turned on.

Time (H)	Phase A (Amp)	Phase B (Amp)	Phase C (Amp)	Power of Phase A (W)	Power of Phase B (W)	Power of Phase C (W)	Total Power (W)
0	25	68	59	4950	13464	11682	30096
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4	25	68	59	4950	13464	11682	30096
5	25	68	59	4950	13464	11682	30096
6	25	68	59	4950	13464	11682	30096
7	26	68	59	5148	13464	11682	30294
8	80.8	146.8	116.8	59998.4	29066.4	23126.4	112191.2
9	108.8	141.8	121.8	65542.4	28076.4	24116.4	117735.2
10	108.8	165.8	116.8	65542.4	32828.4	23126.4	121497.2
11	108.8	178.8	121.8	65542.4	35402.4	24116.4	125061.2
12	110.8	178.8	120.8	65938.4	35402.4	23918.4	125259.2
13	108.8	179.8	118.8	65542.4	35600.4	23522.4	124665.2
14	93.8	184.8	121.8	62572.4	36590.4	24116.4	123279.2
15	87.8	176.8	124.8	61384.4	35006.4	24710.4	121101.2
16	87.8	160.8	120.8	61384.4	31838.4	23918.4	117141.2
17	73.8	116.8	107.8	58612.4	23126.4	21344.4	103083.2
18	25	68	59	4950	13464	11682	30096
19	25	68	59	4950	13464	11682	30096
20	25	68	59	4950	13464	11682	30096
21	25	68	59	4950	13464	11682	30096
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3. Simulation using PV*SOL Software

PV*SOL premium is a simulation program for design, simulation and economic efficiency forecast of grid- connected photovoltaic systems. The settings and input data to PV*SOL software depends on the daily consumption of the building obtained. The simulations will be made for (Grid connected PV System without Battery). There will be three possible scenarios, obtained results are discussed.

3.1 Scenario A:

3.1.1 Site Location

The correct and reliable dimensions were used for the surface, as the length was 53.85m, width 31.5m and the height of sidewalls were 1.25m. The building's location entered to the software in order to evaluate irradiation and temperature data during the year.

3.1.2 Selection of PV Modules:

The Modules were selected from Sunpower Co., which is one of the top ten companies in Modules industry. The Modules were chosen based on number of aspects: High power rating 345W and high efficiency estimated 21.15%. Those are selected in order to fully occupy as much space as possible on the roof. Figure 1 shows the location of Electrical and Electronic Engineering Department on Map. . Figure 2 shows the roof form of the building after arrays are installed.

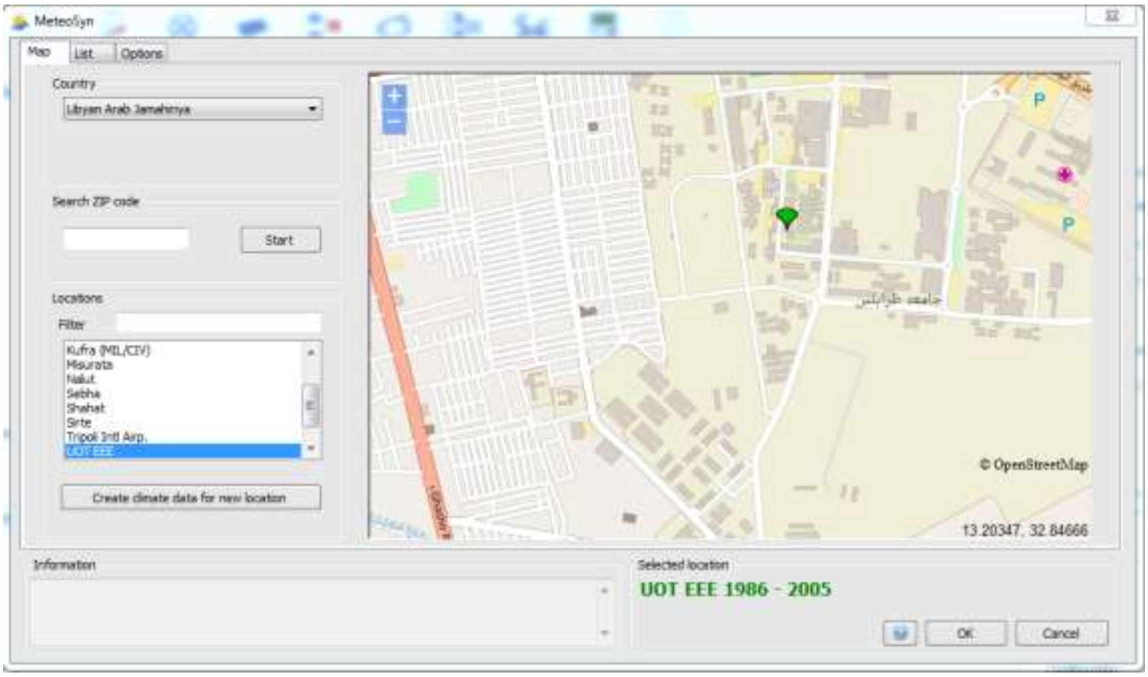


Figure 1 shows the location of Electrical and Electronic Engineering Department on Map.

3.1.3 Module Mounting

To get as much solar energy as possible to minimize shade losses, two important aspects must be taken into consideration when designing array modules [6], which are solar angles and distance between arrays. Figure 3 shows Details of Solar Angles and Distance between Arrays.

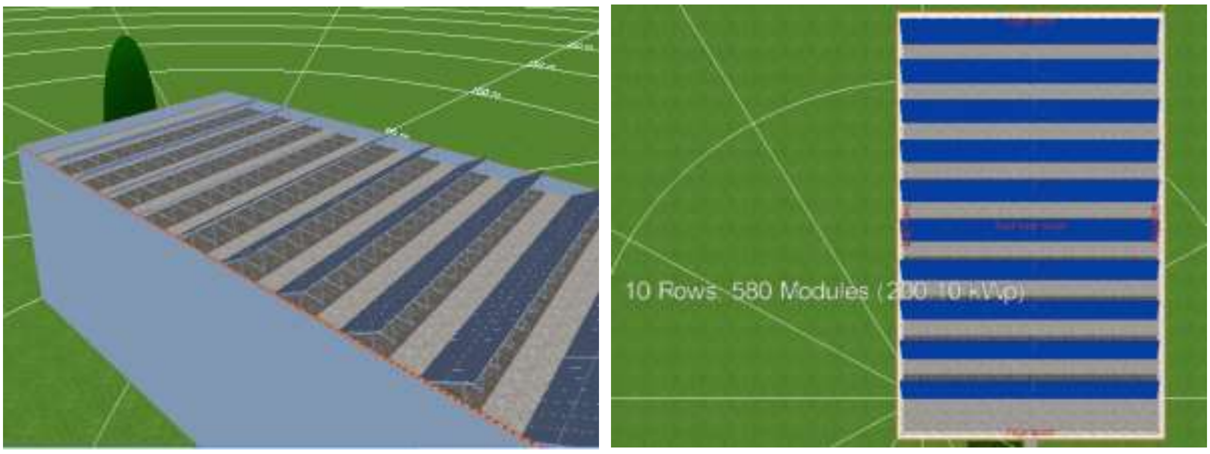
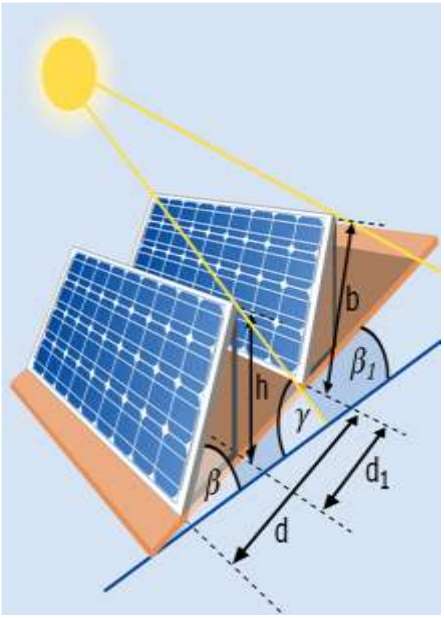


Figure 2 shows roof with panels installed



Input

Reference	Value	Unit
Module Mount Width b	3.123	m
Mount Height h	1.562	m
Resulting Module Inclination β	30.0	°
Resulting Module Orientation	180.0	°
Inclination of Mounting Surface β_1	0.0	°
Orientation of Mounting Surface	180.0	°
Solar Elevation Angle γ	33.71	°
Solar elevation angle applies to UOT EEE	21/12/ 12:00	-

Results

Reference	Value	Unit
Depth of Row d - d_1	2.705	m
Mounting Support Clearance d_1	2.340	m
Row Spacing d	5.045	m

Figure 3 shows Details of Solar Angles and Distance between Arrays.

3.1.4 Selection of the inverter

The selection of inverters depends on number of factors such as sizing factor and configuration quality.

Sizing Factor:

The design of such systems firstly addresses the choice of both, Photovoltaic Generator PVG peak power given in Standard Test Conditions (STC) and the maximum rated power of the central inverter [4]. The ratio between these two values is known as the “Sizing Factor” (SF) is one of the main design parameters of the PV installation and is defined as:

$$SF = \frac{P_{INV,MAX}}{P_{PVG,STC}} \quad (1)$$

During the process of selecting the inverter, number of inverters was chosen from several top companies. One of these inverters called FreeSun FS0230 HE was used for the simulation; table 3 shows configuration details of Inverter at Irradiation 1000W/m^2.

Table 3 configuration details of Inverter at Irradiation 1000W/m^2.

	Temp (°C)	Module	String (10 series modules)	MMP1 (29parallel string)	MMP2 (29 parallel string)
Min Voltage [V]	70	47.5	475	475	475
Max voltage [V]	15	59	590	590	590
Open circuit voltage [V]	-10	74	740	740	740
Voltage [A] under STC	25	57.3	573	573	573
Current [A] under STC	25	6.02	6.02	174.58	174.58
Power [W]	25	345	3450	100050	100050

4. Simulation Result:

The overall model of PV grid-connected system is installed in PV*SOL Software and simulated at standard test condition (STC) with solar irradiance of 1000 W/m^2. PV Generator Surface is 945.8 m2 and a modules capacity of 580 unit. The total annual energy generated by the PV system is 350498 kWh/year and the total direct annual energy consumed by the building is 206248 kWh/year, which is about 50.6% of the total load consumption. The grid was injected by 144263 kWh/year from the total energy generated. Energy production rises during summer period due to the extension of irradiation hours. The performance ratio and capacity factor positively matches with the availability of standard test conditions. Shading losses estimated 9.9% due to the panels and sidewall shades especially for early hours in the morning and before sunset.

5. Feasibility Study

Study of economic feasibility for the project and the benefits expected during the lifetime period [3], this study will also determine all analysis and results using Microsoft Excel. Tables 4 and 5 show details of total capital cost and annual cash flow of PV system.

Table 4 shows the total capital cost

Unit	Capacity of unit (W)	Capacity of unit KW	Cost of unit ($)	Number of unit	Total cost of units ($)
PV Module (W)	345		175.95	580	102051
Inverter (KW)		230	34500	1	34500
Combiner Box (unit)			102	2	204
Panel installation (W)	345		24.15	580	14007
Total capital cost					150762

Table 5 Annual Cash flow of PV System.

Number of years	Total cost of energy before PV system ($/year)	Net cost of energy from Grid after PV system ($/year)	Net cost of energy from PV system ($/year)	Total cost of energy after PV system ($/year)	Actual Revenues ($/year)
Present	$58,147.30	$0.00	$0.00	$0.00	$0.00
1.00	$58,147.30	$8,076.16	$8,138.12	$16,214.28	$41,933.03
2.00	$58,147.30	$8,276.44	$8,105.56	$16,382.01	$41,765.29
3.00	$58,147.30	$8,476.73	$8,073.01	$16,549.74	$41,597.56
4.00	$58,147.30	$8,677.01	$8,040.46	$16,717.47	$41,429.83
5.00	$58,147.30	$8,877.30	$8,007.91	$16,885.20	$41,262.10
6.00	$58,147.30	$9,077.58	$7,975.36	$17,052.94	$41,094.36
7.00	$58,147.30	$9,277.87	$7,942.80	$17,220.67	$40,926.63
8.00	$58,147.30	$9,478.15	$7,910.25	$17,388.40	$40,758.90
9.00	$58,147.30	$9,678.43	$7,877.70	$17,556.13	$40,591.17
10.00	$58,147.30	$9,878.72	$7,845.15	$17,723.86	$40,423.44
11.00	$58,147.30	$10,079.00	$7,812.59	$17,891.60	$40,255.70
12.00	$58,147.30	$10,279.29	$7,780.04	$18,059.33	$40,087.97
13.00	$58,147.30	$10,479.57	$7,747.49	$18,227.06	$39,920.24
14.00	$58,147.30	$10,679.86	$7,714.94	$18,394.79	$39,752.51
15.00	$58,147.30	$10,880.14	$7,682.38	$18,562.53	$39,584.78
16.00	$58,147.30	$11,080.43	$7,649.83	$18,730.26	$39,417.04
17.00	$58,147.30	$11,280.71	$7,617.28	$18,897.99	$39,249.31
18.00	$58,147.30	$11,481.00	$7,584.73	$19,065.72	$39,081.58
19.00	$58,147.30	$11,681.28	$7,552.17	$19,233.45	$38,913.85
20.00	$58,147.30	$11,881.57	$7,519.62	$19,401.19	$38,746.12
21.00	$58,147.30	$12,081.85	$7,487.07	$19,568.92	$38,578.38
22.00	$58,147.30	$12,282.13	$7,454.52	$19,736.65	$38,410.65
23.00	$58,147.30	$12,482.42	$7,421.96	$19,904.38	$38,242.92
24.00	$58,147.30	$12,682.70	$7,389.41	$20,072.11	$38,075.19
25.00	$58,147.30	$12,882.99	$7,356.86	$20,239.85	$37,907.45

Figures 4 and 5 show up all details related to the project cash flow of the PV system and the payback period taking in mind inflation rates during that period. Moreover, this study was done using US dollar currency.

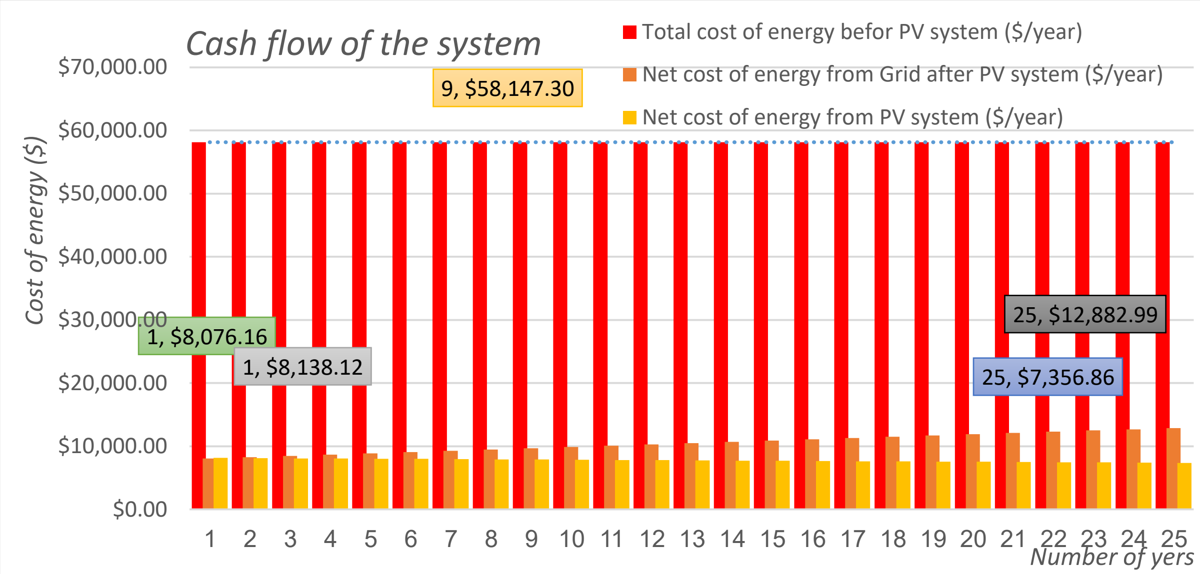


Figure 3 Cash flow of the PV system.

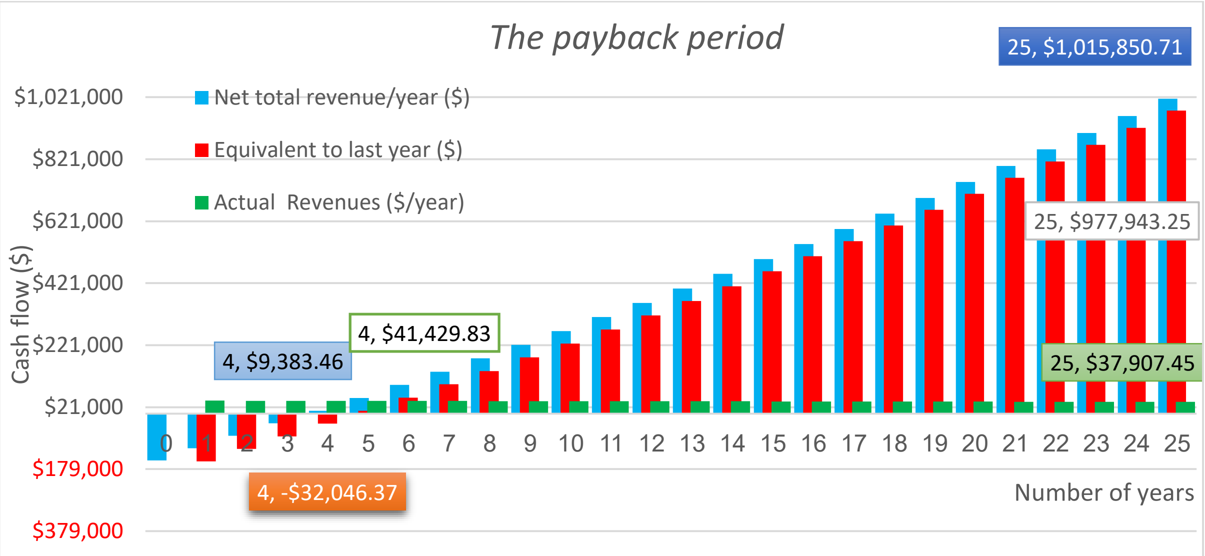


Figure 5 Cash Flow of Payback Period

6. Conclusion

In this study, electric current measurement has been done on the daily energy consumption for the departments building in winter season with and without air conditioners, calculation of power consumption expected in a summer days, was 1612.56 kWh/day double of the consumption measured in a winter day. According the previous measures and calculation, the annual consumption was 407.031 MWh/year for the departments building. A consumption data was entered to software program and the right modules were selected with high efficiency and rated power, choosing the appropriate inverter taking in consideration its size to be less than 100% in order to not have energy wastages. In this scenario the PV generator surface is 945.8 m2 and the number of modules is 580 units, these modules have given a rated output power of 200.1 kWp. The results provided were satisfied and beneficial as the annual energy produced is 350,498 kWh/year , the capacity factor 19.99%, the performance ratio is 79.14% ,the shading losses is 9.9%/year, the net profit 650,332.47$ and payback period was 4 year.

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