SYZING AND ANALISYS OF A PHOTOVOLTAIC SYSTEM FOR SELF-CONSUMPTION

ABSTRACT

The use of photovoltaic systems is a key aspect for a sustainable energy future because allows the use of renewable energy, prevenient from the Sun, to produce the electricity needed. The present paper proposes the sizing of a PV system and his analysis to see how much impact it has on a company energy footprint and how much money they can save by not using electricity from the grid. For this project was used a simulator provided by SMA, showing that it's possible to invest on a PV system and get the payback in a few years.

Index Terms—Energy footprint; Photovoltaic System; Renewable Energy; Self-consumption.

1. INTRODUCTION

In our world, there is an increasing trend of demand for electricity, extreme urgency to reduce the profound reliance on fossil fuels for power production and hence emissions, and energy security, among others. Intermittent energy technologies, such as wind and solar PV, are projected to reduce 80% to 90% of greenhouse gas (GHG) emissions by the year 2050 [1].

The photovoltaic systems (PV systems) are a great way to reduce the electrical energy produced by non-renewable sources because, in this systems, the electricity is obtained through the direct conversion of the sunlight. These systems follow a distributed production regime to promote the production near the point of consumption, reducing the electrical losses [2]. The integration of the electricity generated by a photovoltaic system into the grid can create problems - as excess of production – but can be solved through the development of adequate storage units [3].

Self-consumption also increases the market competition, because encourages new services that better suited the needs and in this way, the consumer becomes active in the investments transitions. Also, on residential and services, solar energy used for self-consumption protect the costumer from the volatility of the energy prices [4].

The paper presents a simulation of the sizing of a PV system to be used by a commercial store and his installation and is structured considering the following sections: Section II describes the proposed methodology; Section III presents a case study; and Section IV presents the main conclusions of the paper.

2, PHOTOCOLTAIC SOLAR ENERGY

The photovoltaic cell is a device made of a semiconductor material that when exposed to sunlight harvest an electron and creating a gap. The principle of the PV cell is to force the electrons to advance to the opposite side of the cell, producing a potential difference and consequently an electrical voltage. The electricity generated by the cells is formed in direct current (DC) and can be used or stored in batteries [5].

These systems are composed with a PV panel – association of PV cells encapsulated in two layers of EVA between a front glass slide and a thermoplastic polymer layer. The inverter is responsible for transforming the continuous electric current produced by the panels into alternated current (AC). This current can be injected on the grid or used for selfconsumption [6].

The electric conductor transports the electricity from its generation to the final consumer and the whole system is controlled by an electrical panel that it's responsible for measuring all the consumptions [7].

3. CASE STUDY

A. Company and building

This project was done for a commercial store – Intermarché – located at Vila das Aves, Portugal, and is open to the public from 8AM to 22PM. The building has an area of 4000m^2 and about 2800m^2 of useful area. It is composed by two floors above the ground and has two slopes. The first floor consists in service to the public, storing area, a video surveillance room and an engine room. Regarding the second floor, this one has a much lower area, being only composed by offices for the administration. The roof of the building is made of prefabricated sandwich material and is supported by a structure of iron beams.

B. Analysis of the Electric Energy Bill

A photovoltaic sizing must be carried out in order to ensure maximum profitability of the same in order to obtain the shortest possible amortization period. Therefore, it is advisable to dimension the month of least consumption, in order to avoid waste of energy. These amounts are collected from the electricity bills of the company that contain the quantities consumed and the periods in which it was consumed. With these elements it is possible to determine the power of the PV generator to optimize the investment.

After analyzing the consumptions, it is verified that the highest ones are found during the daytime regime, favoring the installation of a PV system because the consumption occurs during the periods where there is more sunlight, reducing significantly the bill during the hours where tariffs are higher.

From this table it's possible to see that the consumption varies throughout the year. This variation is directly related to the difference between the interior and exterior temperature of the building and the expenses necessary to maintain the desired interior temperature. Therefore, in order to avoid injecting electricity into the grid, this project should eliminate most of the needs in the months when consumption is lower.

C. Estimates of Photovoltaic Energy Produced

The location in question has a good solar exposer, having a peak solar hour (PSH) of 5.21h, which means that, each day, in average, exists 5.21 hours of hypothetical irradiation of 1000W/m2 [8].

TABLE I. ELECTICAL ENERGY CONSUMPTION

	Peak			Full	Normal Empty		Super Empty	
	h	kWh	h	kWh	h	kWh	h	kWh
Jan	110	14916	304	32106	201	18837	124	4879
Feb	100	14421	268	29794	192	16272	112	4524
Mar	106	14006	289	31497	228	18464	124	5337
Apr	66	8138	336	35887	198	20167	120	6866
May	63	7535	343	36102	211	23456	124	7527
June	66	8201	322	39545	215	21995	120	6952
July	69	8933	350	41899	201	18357	124	6934
Aug	63	7898	329	37487	228	22049	124	6561
Sept	66	7833	336	36625	198	17006	120	6134
Oct	76	9131	340	34777	201	17370	124	6080
Nov	105	12837	275	28448	225	17697	120	5573
Dec	115	14916	304	32106	201	18837	124	4879
T		128765		416273		230507		72246

After analyzing the load diagrams obtained, and showed on figure 1., it is possible to conclude that a power of 100kWp of photovoltaic is a good solution to implement in the building to guaranteed that all the energy available from the PV installation is consumed by the company and not injected into the national electricity grid, because the best performing day requires approximately that power.

Figure 1. Estimates of PV energy produced (SMA Simulator)

In order to obtain this power, it's going to be used 324 PV panels of 305W, corresponding to an installed peak power of 98.82kW. To convert the DC electrical energy generated to AC power are used four inverters from SMA with 25kW of nominal power. Each of these inverters has two inputs. In the first will be connected 3 strings with 17 PV panels each and in the second input will be connected 2 strings with 15 panels each. This configuration was obtained using the SMA simulator, available online, and it gives the user the better system configuration, using SMA inverters.

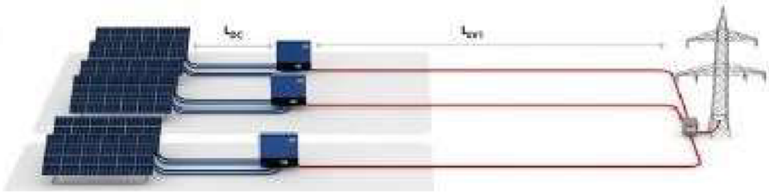

Figure 2. General configuration of the PV installation (SMA Simulator)

D. Physical Layout of the PV modules

As the slope of the roof is very low and is oriented with a very high azimuth angle relative to the geographical South, the PV panels are installed orientated to South. The optimized panel inclination for the zone in question will be around 30º and the spacing of the panels will be obtained to a minimum solar height which will prevent the shading. This panels will also be installed fixed in a support structure.

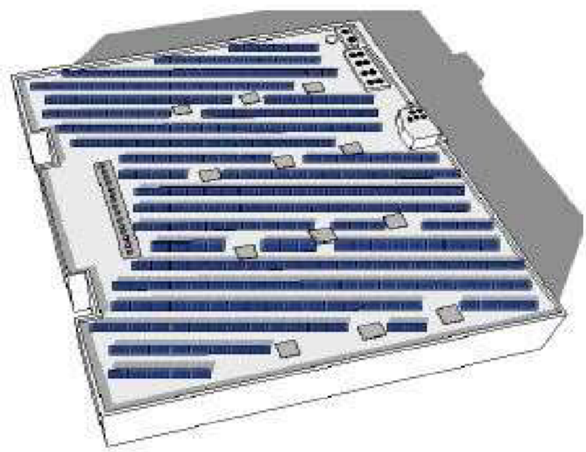

Figure 3. Physical Layout of the PV modules (Sketchup)

E. Real Electrical Energy Produced

The energy produced by the PV installation will depend on several factors, such as solar irradiation, temperature, equipment efficiency, and others. The solution described above for a better optimization, resulted in a monthly energy output of approximately 153MWh. This data was obtained by PVGIS software, for 100kW of PV power, losses due to temperature and low irradiance of 11.2%, losses due to reflectance effects of 2.7% and other losses (cables, inverter, etc.) of 5%, that gives a total of 18% in losses [9].

TABLE II. ELECTRICAL ENERGY PRODUCTION

	Global Irradiation [kWh/m²]	Electricity Produced [kWh]
Jan	94.3	8120
Feb	120	10200
Mar	168	13800
Apr	169	13700
May	192	15400
June	200	15600
July	218	17000
Aug	217	16800
Sept	188	14800
Oct	144	11800
Nov	102	8620
Dec	88.4	7630
T	1,900.7	153470

From the table it's possible to see that the production generated it is instantly consumed on the building by selfconsumption.

F. Annual Savings

The electricity acquire by the store is contracted to Endesa, with a four-hour contract and 228kW of contracted power. The tariff is divided into four plots: tip (0.107413€/kWh); full (0.095732€/kWh); normal empty (0.072495€/kWh); and super empty (0.066205/kWh).

The investment amortization is achieved considering the savings in the electric energy bill.

As the electricity production is during the day, has the advantage that the tariffs in these periods are the highest, allowing a faster amortization.

It is also necessary to consider the savings in the power surcharge at rush hours, of around 2,502€ per year and the electricity tax, of around 155€. In total, the annual savings of the system will be 17,869.68€ per year.

For the PV system installation, with all the items described above, it requires an investment of 99,241.91€.

G. Feasibility Analysis

The main objective of this analysis is to calculate several feasibility indicators, based on the evaluation of the cash flows generated, including the Internal Rate of Return (IRR), the NET Adjusted Value (NPV) and the Amortization Period (Payback).

For a better accuracy, the calculations were made considering the NPV corresponding to the cash flow of each year until the total amortization of the investment is verified.

For these calculations, the capital opportunity cost was considered to be 2.9% and an increase of 2.5% per year of the electricity tariff. With all these factors, the amortization period estimated is 5 and a half years.

TABLE III. AMORTIZATION PERIOD

	Cash Flow	NVP	Accumulated Cash Flow
0	-99241.91	-99241.91	-99241.91
1	17869.68	17366.06	-81875.84
2	18316.42	17298.56	-64577.28
3	18774.33	17231.31	-47345.97
4	19243.69	17164.33	-30181.64
5	19724.78	17097.61	-13084.03
6	20217.90	20217.90	7133.88
7	20723.35	2072335	27857.23

4. CONCLUSIONS

This paper presents how to sizing a photovoltaic system and all the components involved to produce electricity from a non-renewable energy source, essential to reduce the carbon footprint that we face at the moment. It also shows how to calculate the amortization period to see if it is viable to install the system, and shows that a PV system it's a good solution to produce electrical energy during the day.

As shown before, a PV system is a very reliable system to provide electricity and although the investment maybe a little bit expensive at the moment, in only 5 and a half years it is possible to amortize it.

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