Dimensioning and Economic Feasibility Analysis of a Photovoltaic System Installed in a Manaus-AM Commercial Area

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Abstract

This study aims to demonstrate the application of sizing and an analysis regarding the economic viability of a grid connected Photovoltaic System for a trade located in a commercial area of Manaus - AM, considering the agents that influence the initial investment analysis. and end of project. Exposing the relevant concepts around grid-connected photovoltaic systems (SFCR) establishing regulatory standards governing insertion for distributed generation micro and mini connection systems and methods for project investment analysis. Presenting the analysis effect of the economic viability of the system using the discounted payback investment methods, the energy consumption, in kWh, in the trade and investment profit and, finally, the results and conclusions obtained through the method of Discounted Payback analysis, which shows the viability of the project from a technical and economic point of view, in order to meet and contribute to sustainability and conservation of the environment.

Keywords: photovoltaic system; energy consumption; on grid.

1. Introduction

One of the alternative sources of energy found for electric power generation was solar energy, since it does not pollute the environment, which occurs through the photovoltaic effect, a phenomenon discovered in 1939, Edmond Becquerel verified the emergence of the photovoltaic effect Through the metal plates, platinum or silver, dipped in the electrolyte produced a potential difference in the exposed semiconductor material when subjected to light [1]. As this is a location of the intertropical convergence zone cut to the north by the equator line, this gives Brazil a great advantage in the potential of solar energy generation during the whole period of the year. through solar radiation [2].

The most common semiconductor material for their production and pure silicon offers conduction, silicon when it is in pure state and a material with low efficiency, and may have a poor conduction capacity, however, and precise goes through a step purification and subsequently by a doping step. The module is the generator device, consists of a set of interconnected and connected photovoltaic cells, generating electricity through sunlight. Since it is made up of photovoltaic cells constructed from the main existing technologies, monocrystalline silicon (c-Si) is the most efficient, polycrystalline (p-Si) and its efficiency is slightly lower than that of (c-Si). having the advantage of having a lower production cost, and those of hydrogenated amorphous silicon (a-Si) which stand out for their better performance compared to others in terms of energy production [3].

In Brazil photovoltaic solar energy has been playing a significant role in the production of energy through solar panels, and may have a 44% growth in installed solar energy capacity in 2019, surpassing the 3.3 GW mark of the source in operation for projections in distributed generation (GD), Must total 628.5 MW in solar capacity to Brazil [4].

Within this context, the present work aims to expose the sizing and implementation of a grid connected photovoltaic system (SFCR), showing the importance of using solar panels and analyzing the economic viability of this system to the present day as a means of reducing consumption. energy production and increased energy production. Through implementation the project aims to show how economically viable is the investment of this installed energy source in an area, observed through the calculation of discounted Payback, along with the distributed generation of energy, which currently offers greater efficiency in the energy matrix. to attend and contribute to the sustainability and conservation of the environment.

2. Theoretical Referential

2.1 Grid connected photovoltaic systems (SFCR)

In order to reduce barriers to the connection of small power plants to the distribution grid (although using clean and renewable energy sources or energy-efficient cogeneration), laws have been created in Brazil which are governed by the National Energy Agency. Electricity by means of Normative Resolution No. 482/2012 which establishes the general conditions for Distributed Microgeneration and Minigeneration and the energy compensation systems in which the producer has the right to generate part of the electricity he consumes is and compensated the energy value. active electric. Provided the accumulation of credits over a period of days, if the surplus is not used by the producer and injected into the network, it can be used in other properties of the same holder, if met by the same concessionaire [5] [6]. described below:

• Distributed microgeneration: For generating units connected to the low voltage distribution network must meet the installed power less than or equal to 75KW and using clean energy sources such as wind, solar, biomass, hydraulic and cogeneration, connected to the distribution network.

• Distributed Mining: For generating units connected to the low voltage distribution grid with installed power greater than 75 KW and less than 5 MW using clean power sources connected to the distribution grid.

Photovoltaic systems connected to the electric grid, known as on-grid systems, operate in parallel with the electricity grid. Its structure is made from blocks mounted on frames, usually aluminum and the material used for its blocks because of its greater rigidity and handling. Its main advantages are not requiring energy storage, they can be deployed in any harsh environment that has sufficient solar radiation to meet the desired demand, and seen as efficient and inexpensive compared to existing ones, these systems added in large amount are capable of unclog the distribution grid at peak times, as it can be installed in conjunction with the local power system, as shown in Figure 1. [7] [8].

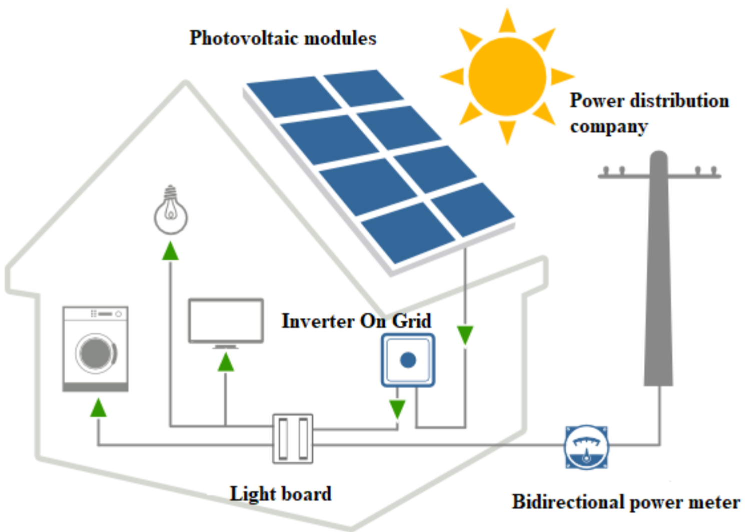

Figure 1. Network Attached Photovoltaic Systems (SFCR).
Source: Solar Energy, 2019.

This system can basically consist of one or more photovoltaic modules and a set of equipment that are part of your system the photovoltaic panel or module, DC-AC converter (inverter) system, maximum power point follower (MPPT), devices protection, electrical wiring, terminals, overvoltage and lightning systems [9].

Regarding the state of Amazonas, the concessionaire responsible for such regulations is Eletrobrás Amazonas Energia, which supplies energy to consumers [10].

3. Methodology

The area of study of the sizing and analysis of the economic evaluation and a trade of auto parts of motorcycles, located in the Cidade Nova neighborhood, in the north of the city of Manaus - AM, the trade presents in a place of easy access since the circulation of vehicles to the access of consumers who buy the goods and services offered in commerce as motorcycle parts among others. In this area there is an extremely favorable level of incidence of solar rays that was possible through tests to analyze the energy conversion from the 100% electrical effect in the studied area.

Using PVSYST V6 Software. 78 will be effective to aid in the design of the SFCR'S, which positively benefited from the survey of the solar resource at the study site and the total survey needed for photovoltaic panels, the inverter power to meet 95% of the commercial consumption. Where it was necessary for the measurement of data on the geographical coordinates of the site with a latitude measurement of -3.13 ° S, longitude of -60.02 ° W and an altitude of 72 m, the roof angle of the self-producer has an inclination of 8 °, is Azimuth and -20 ° .The data collected comprise the historical annual radiation series as well as the temperature of the respective radiation.

In Figure 2 and presented to the roof face available for solar panel installation, during the morning the left-hand face identified with red receives the lowest solar radiation. The data described above helped significantly in the first stage of system deployment in the commercial area exemplified in the figure below.

Figure 2. System installation location.
Source: Google Maps, 2019.

For the sizing of the system was evaluated the possible solar resource referring to the location of the installation of the system, analysis of electricity tariffs manifested in the commercial area, it was necessary to collect the consumption data of the commerce, to describe the cost of energy generated, making a comparison with the conventional system, and later with the photovoltaic system connected to the grid SFCR's, using the appropriate characteristics of the distributed generation system. To analyze the economic viability of the system, the investment methods were used through discounted payback.

4. Analysis and Discussion of Results

4.1 Design of grid-connected photovoltaic system

This stage presents the realization of the SFCR sizing, given through the PVSYST V6.78 software of the SFCR, which has the capacity to generate electricity to offset 95% of the annual consumption of 17,965.17 kWh / year of trade of the auto producer with main purpose is the capacity to produce 18,864.25 Mwh /

year (95%) of energy in the system, as shown in Figure 3.

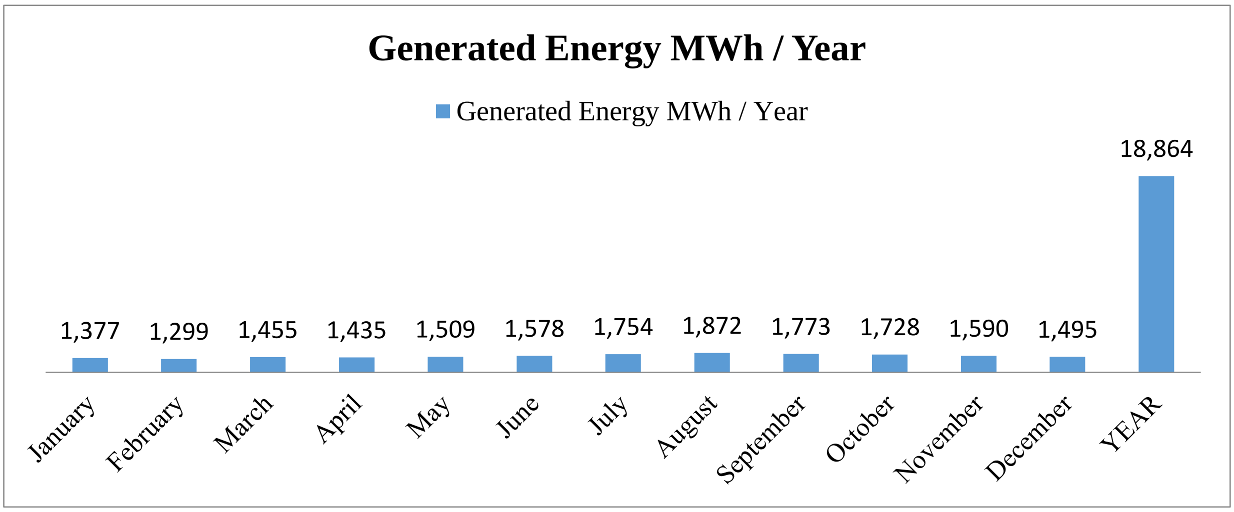

Figure 3. Economic results of the compensated generated energy of the on-grid system.

Table 1 lists the equipment required for the assembly of the SFCR, such as photovoltaic modules, the inverters and the metal structure required for fixing, as well as the physical description and the total value of the components that include the design and installation services. Based on 40 precise photovoltaic modules, byd - phk -36 model with a maximum power of 330 wp, 25 years linear performance guarantee, average cell efficiency up to 18.8%, in compliance with the 12.73 kwp total power system as well as the power of 2 on grid inverters that have anti-islanding protection and internal DC switch. The inverter used has a maximum input DC power of up to 6000 W, rated output power of 6000 VA and a maximum efficiency of 97.8%.

Table 1. Specifications and total value of components for the grid-connected solar photovoltaic system - SFCR.

40 PC 330W BYD Photovoltaic Module - PHK-36	48 PC Metal Tile Bracket - Spin
2 PC Inverter 5kW 2MPPT (Fronius Primo 5.0) 220V	8 PC Aluminum Track 2.1 meters - Spin
2 PC Stringbox 2 Inputs + 2 Output - Clamper	16 PC Aluminum Rail 4.2 meters - Spin
100 MT 6mm² Solar Cable - Black	72 PC Intermediate AL Clamp - Spin
100 MT 6mm² Solar Cable – Red	16 PC Clamp AL terminal - Spin
4 PC MC4 MC Connector – Male	16 PC Aluminum Rail Junction - Spin
4 PC MC4 MC Connector - Female	2 6.6KWP Kits
48 PC Metal Tile Bracket – Spin	Accessories and Labor
01 PHOTOVOLTAIC GENERATOR KIT 6KW	UNIT VALUE R $
Total amount without tax: R $	48.000,00
Total amount with tax: R $	**48.000,00**

* Values in Brazilian Real

The equipment used in this system is of efficient and modern technology, allowing an estimate of an average of 25 years or more of its useful life.

4.2. Local Energy Consumption in 2018.

For the design of the SFCR, it was necessary to first survey the energy consumption of the consumer unit. Table 2 shows the monthly consumption for a twelve-month period, from January to December 2018. During this period, the energy used was fully supplied by the local energy concessionaire.

Table 2. Energy consumption in trade in 2018.

Month	Monthly consumption reading (kWh / month)	Amount paid
January	1421,35	R$ 1.336,07
February	1412,56	R$ 1.327,81
March	1358,31	R$ 1.276,81
April	1351,88	R$ 1.270,77
May	1541,56	R$ 1.449,07
June	1536,52	R$ 1.444,33
July	1510,25	R$ 1.419,64
August	1589,79	R$ 1.494,40
September	1504,89	R$ 1.414,60
October	1624,02	R$ 1.526,58
November	1617,65	R$ 1.520,59
December	1496,39	R$ 1.406,61
Total	**17965,17**	**R$ 16.887,26**

* Values in Brazilian Real

Looking at the monthly consumption shown in Table 2, there is a noticeable monthly increase in the amount of energy consumed in the establishment implying a growth in financial costs. Among the factors that contributed to support this analysis of consumption in commerce, is the period of the day when there is the highest demand for energy in the concession area. It is noted that in May, from 2018, there is an increase in the energy bill, compared to previous months, because during this period there is a transition from the humid period to the dry period in the region, with the increase in temperature use. more frequently air conditioners are used. This behavior remains until the second half of November, reflecting a reduction in the value of energy consumption in December. However, it is important to emphasize that the financial costs for energy consumption increase considerably also due to changes in the energy tariff.

4.3. Characterization of Consumption and Self-Consumption Percentage

Following the installation of the SFCR at the study site, for the first two months of system implementation there was a considerable decrease in financial costs with the payment of the energy consumption tariff to the local utility. The system was installed and ready for operation in May 2019, already showing savings over the next two months, as shown in Table 3.

Table 3. Input Savings with Installing an SFCR.

Period	Monthly Consumption (kWh / month)	Amount payable with SFCR
(months)	1.444,33	R$ 299,62
June	1.419,64	R$ 181,29
July	**R$ 2.383,06**	

* Values in Brazilian Real

According to Table 3 it is possible to realize the financial savings after the installation of the SFCR. It is noteworthy that the system meets expectations, if we observe that in July 2018 the amount to be paid for energy consumption was R $ 1,419.64 and, in the same period, with the system implemented the amount to be paid by Energy consumption was only R $ 181.29. The SFCR produced a consumer power generation credit of R $ 897.40, as shown in Table 4, where we have the monthly energy consumption billing for the location, referring to the July period issued by the concessionaire.

Table 4. July energy bill analysis with SFCR installed.

Readings	**Meter**	**Current Reading**	**previous reading**	**Billed Constant**	**NPL**	**Measured Consumption**	**Invoiced Consumption**
Consumption	11162018	22353	20951	1,00000	5	1402	1402
Consumption Period: 06/30/2019 to 07/30/2019							

Billed Items	Tax Free Rate	Value
Consumption 131 kWh to 0.941413	0.706060	123,32
Consumption 1,271 kWh at 0.706060	0.706060	**897,40**
Public Lighting Contribution (CLP)		57,97
Off-End Generation Credit		**-897,40**
Reverse Waste Off Tip - 1,271		

Description of Greatness	Current Reading	**previous reading**	Constant	Recorder
In Active Tip	0	0	1,00000	0
En Active Off Tip	22353	20951	1,00000	1402
En Reverse	0	0	1,00000	0
Calculation basis **(*)**	Aliquot **(*)**	ICMS Value **(*)**	Expiry **27/08/2019**	Amount Payable **R$ 181,29**

* Values in Brazilian Real

Siqueira, a student at the Federal University of Juiz de Fora, conducted an economic feasibility study on a photovoltaic solar energy system applied to a three-phase religious temple in the city of Juiz de Fora - MG. With the main objective of having an energy compensation in place, in which the consumer could pay up to 2,224.80 kwh of energy per month, considering the monthly amount saved in the first year of installation of the system of R $ 11,480.12 during the first one. year. Thus, average monthly savings are R $ 956.67 enabling the SFCR Microgeneration system [11]. Finally, as the system generation projections depend only on favorable climatic conditions for the use of this type of energy generation, and are based on historical averages, it is possible to obtain positive and satisfactory results achieved with the implementation of the SFCR´S, once that meet initial expectations by solving the design hypothesis that helps reduce high transmission and distribution costs by bringing generation close to final consumption.

To perform the economic analysis of the photovoltaic system it was considered a simulation of the amounts to be paid for the energy consumption by the utility using the PVSYST V6 software. 78 presented in Table 5.

Table 5. Input savings by installing an SFCR.

Period (months)	Amount payable without SFCR	Amount payable with SFCR
12	R$ 16.887,26	2.809,86
Economy	**R$ 14.077,40**	

*Values in Brazilian Real

Thus, the discounted payback was applied to analyze the financial viability of the project, with the initial investment (I) as a result of cash flow with investment gain (F_C), and system operation and maintenance costs (M_S). . Thus, the discounted payback was applied to analyze the financial viability of the project.

$$Payback = \frac{I}{(F_C) - (M_S)} = \frac{48.000,00}{14.077,40 - 600.00} = 3,5\ years$$

*Values in Brazilian Real

The discounted payback calculation estimates a financial return after the implementation of the SFCR at 3.5 years proving the economic viability of the project, as the useful life for the SFCR under study is, on average, 6 years. The estimated financial return as a function of solar panel life can be observed in Figure 4, where it is possible to track the annual financial savings for a period of 25 years.

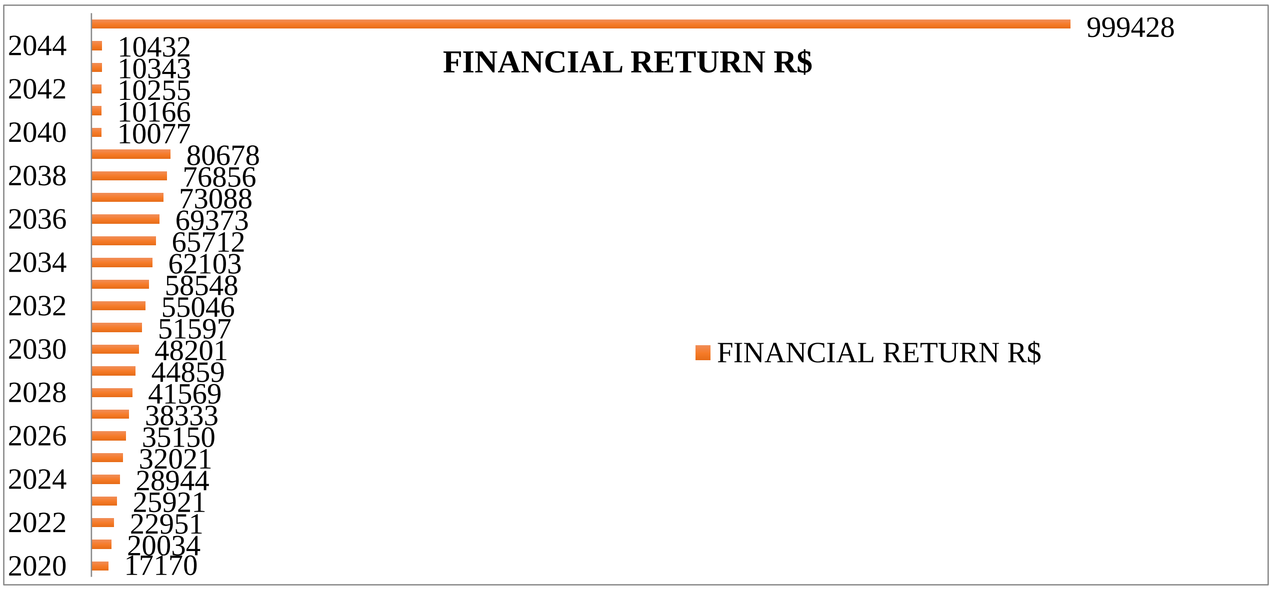

Figure 4. Economic result of the financial return of the SFCR system.
*Values in Brazilian Real

The results obtained in this system show the initial value of R $ 48,000.00 of investment for the installation and operation of the SFCR. This amount is recovered by analyzing the discounted payback method in 3.5 years. Therefore, this project is technically effective and has relevant economic viability, which can bring to the scenario under study numerous advantages, such as increased profitability of commercial activity and use of clean energy. The project becomes a model to be followed in the city of Manaus-AM.

5. Conclusion

According to the development of the project, we found that it is possible to generate pure electricity using clean and renewable energy sources or high energy efficiency cogeneration for SFCR'S to serve medium and low voltage consumers. It is concluded that with the incentive of the regulatory norm governed by the national agency of No. 482/2012, April 17, 2012 favored positively for the insertion of the self producer in the production of his own energy following the parameters of Microgeneration and Distributed Minigeneration and the systems energy compensation was cited throughout the study.

In general terms through the collected data, it was possible to carry out the economic evaluation for the project showing to be economically viable technically and economically with a guarantee of 25 years efficiency of clean energy production, which was observed by the payback method. discounted which showed an initial return on investment of approximately 3.5 years worth less than 25 years of project life.

It is valid that the power compensation connection standard in Brazil offers favorable conditions for the use of this type of power generation in the capital of Manaus-Am, not only due to its intertropical location, but also for the great availability of natural and territorial resources, and by the characteristics of your electrical system.

For future studies in the area, a study is recommended on the environmental impacts caused by poor disposal of photovoltaic technology after reaching its useful life. as is also suggested later work on the evolution of the improvement of government incentives about the low insertion of this technology for producers.

6. Acknowledgment

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