

Feasibility Analysis of the Solar Energy System in Civil Construction

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Abstract— *The use of clean energy from renewable natural resources, replacing what is commonly used is seen as a solution to environment preservation and cost savings with energy generation and distribution. Therefore, the use of solar irradiation for the generation of electric energy is a viable option for regions that present climatic conditions favorable to this technology, as the state of Tocantins does. It is analyzed the feasibility of the energy generation system capable of supplying a building of up to 50m² with monthly consumption of 800kWh using the solar potential of the region. Following the norm that regulates the micro generation of energy in the country, according to the regulatory agency (ANEEL), presenting the components of the system and punctuating the advantages of its implementation. With a survey of energy costs based on the value determined by the concessionaire and the feasibility of deploying solar energy according to the monthly solar irradiation in conjunction with the equipment costs of the system. According to the results obtained from the method of implantation of the system, which is compact and flexible and capable of suiting any existing building structure, which allows a lifespan of close to 25 years, presenting a return on investment in 60 months of operation and providing a 75% reduction in the monthly energy bill, disregarding that this percentage may increase according to possible tariff readjustments. Being a clean energy that causes very low environmental impact in relation to the other methods commonly.*

Keywords— *Solar Energy, Renovable Sources, Economy, Energy Generation.*

I. INTRODUCTION

Currently, Brazil is still very dependent on two sources of energy: hydro and thermal (natural gas and coal), but after the rationing of electric energy occurred in 2001, there was a need for a bigger diversification of the brazilian energy matrix. With this, it has become increasingly constant the

implementation of constructive methods that allow greater efficiency of a building, with respect to its daily consumption of energy. The adequacy of construction to these clean technologies provide higher performance and lower monthly consumption costs, using alternative sources for the generation of renewable energy present in nature.

With the regularization in the Ministry of Mines and Energy through the ANEEL (National Agency of Electric Energy), for the micro and mini generation distributed to the electric power distribution systems and the electric energy compensation system, the investment in this segment became even more profitable. This would allow a change in the current scenario where the majority of Brazilian electricity comes from hydroelectric plants, representing 61.1% (ANEEL, 2017) of the installed capacity, which even being considered low pollutants they still cause considerable environmental impacts.

Normative Resolution No. 482, of April 17, 2017, establishes the general conditions for the access of micro generation and mini-generation distributed to the distribution systems of electric energy, the system of compensation of electric energy, and gives other measures from the following articles:

Article 1 Establish the general conditions for the access of micro generation and mini-generation distributed to the electric energy distribution systems and the electric energy compensation system. (Redaction given by REN ANEEL 687, 11.24.2015).

Article 2 establishes micro-generation distributed to the power generating central, with installed power less than or equal to 75 kW and that uses qualified cogeneration. And mini distributed generation is a powerhouse of electric energy with an installed power above 75 kW and less than or equal to 3 MW for water sources or less than or equal to 5 MW for qualified cogeneration, according to ANEEL regulations, or for other renewable sources of electricity,

connected in the distribution network through facilities of consumer units. (Redaction given by REN ANEEL 687, 11.11.2015.)

The geographic location of the state of Tocantins makes it to be in the Brazilian solar belt, and the aggravating of the intensity of the solar rays of the region with the increase of the temperature every year, it propitiates the installation of photovoltaic systems of generation of energy. This phenomenon was observed by the conversion of solar radiation into electricity by means of semiconductor materials obtaining solar photovoltaic energy, that in 1839 by the scientist Alexandre Edmond Becquerel, where the physicist verified that plates of metal, of platinum or silver, dipped in an electrolyte, produced a small potential difference when exposed to light. And later in 1877 the American inventors W. G. Adams and R. E. Day used the photo-conductive properties of selenium to develop the first solid device of producing electricity by exposure to light. It was a film of selenium deposited on an iron substrate and with a second semitransparent gold film that served as a frontal contact. It presented conversion yield in the range of 0.5%, but, even with the low efficiency presented, However, even with the low efficiency presented, Werner Siemens, a German engineer, marketed selenium cells as photometers for cameras (VALLÊRA et al., 2006).

Due to the energy crisis that settled in the world in 1973, the price of oil quadrupled and this aggravating added to the climatic changes occurred in the same period caused an environmental concern, taking the great world powers to invest heavily in the photovoltaic technology, seeking a reduction of the costs of generation from the sun. These investments provided a reduction of about 80% in the cost of electricity from this form of generation in less than a decade. The threat of lack of energy and climate disasters led to the creation of the first photovoltaic generation park in 1982 in the USA and solar roofs in 1990 in Germany and in 1993 in Japan. Researchs have shown that reducing installation costs of photovoltaic cells is not only due to technological development, but also to increased production and improvements in manufacturing techniques. With this cost reduction it is believed that solar panels would be a generation alternative with competitive costs to that of conventional energy (GUIMARÃES, 2012).

By means of Technical Note 05/2017, published by the Ministry of Mines and Energy in July of the same year, the Federal Government announced the privatization of the Eletrobrás System hydroelectric generator park, which could lead to a increase of 7% in energy bills of the Brazilian population, which has been growing since 1995. The growth of the world's environmental discourse related to climate change, which is discussed at the United

Nations Conference on the Environment, has made the government in agreement with the credit lines (banks) to provide a high percentage of resources for the implementation of "green systems", which aim at preserving the environment.

Due to these factors, the present work had the objective of analyzing the economic viability for the implementation of an energy generation system for the supply of a 50 m² residence in the state of Tocantins.

II. METODOLOGY

The study was developed based on solar radiation data from CRESERB - Reference Center for Solar and Wind Energy Sérgio de S. Brito in the last 12 months, through the meteorological station of Porto Nacional (Latitude: 10.5 ° S, 48.417206 ° O) with an altitude of 239.2 meters at sea level, which is part of the network of stations of the INMET-National Institute of Meteorology and is 60 km from Palmas the capital of Tocantins.

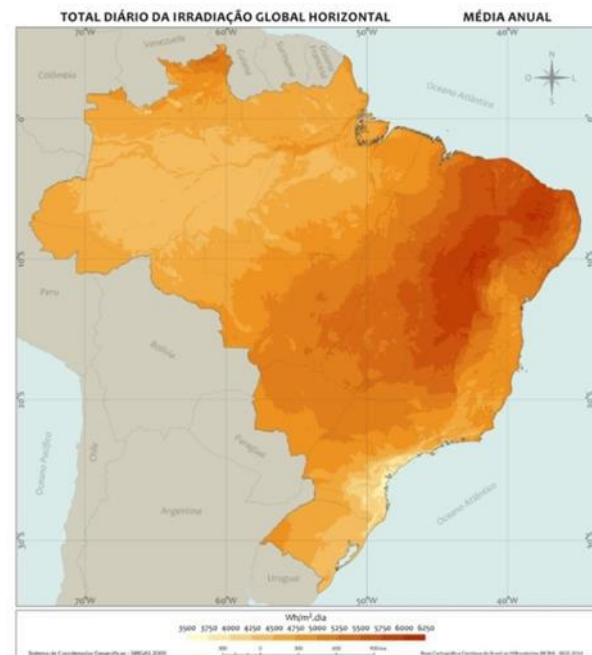


Fig. 1: Global Average Irradiation in Brazil

Source: Geographic Coordinate System

The survey of the system's installation costs was based on a project executed in Porto Nacional at the beginning of the year 2018 in a residence located in the center of the city, taking into account that the project was dimensioned for a construction model bigger than the one proposed in the pre-project. There was a need to resize and evaluate the final cost for the execution of the solar energy generation system in a 50 m² residential project.

The electricity costs of the residence are based on the tariffs defined by the (ENERGISA) concessionaire of electric power of the state of Tocantins. This unit value is determined by ANEEL and is used to calculate the

monthly billing of the electricity distribution system users for the use of the system and energy consumption.

Since the year 2015, energy bills have started to join the Tariff Flags System, which presents the following modalities: green, yellow and red. They indicate whether there will be an increase in the amount of energy to be passed on to the final consumer, according to the characteristics of each modality:

Green flag: favorable conditions of power generation. The fare does not suffer any increase;

Yellow flag: less favorable generation conditions. The tariff is increased by the amount of R\$ 0,010 for each kilowatt-hour kWh consumed;

Red flag - Level 1: more costly generation conditions. The tariff is increased by the amount of R\$ 0,030 for each kilowatt-hour kWh consumed.

Red Flag - Level 2: even more costly conditions of generation. The tariff is increased by the amount of R\$ 0,050 for each kilowatt-hour kWh consumed.

This division happens according to the time of year when the power plants have a decrease in their production because of the water level of the reservoir.

The system is installed in parallel with the grid, thus allowing its power supply both by the photovoltaic system and the grid, which ensures the power supply of the charges during periods of high and low light intensity. This activity is only possible by using electronic components of modulated power output.

The photovoltaic systems connected to the grid (SFCRs) are basically composed of: PV panels and frequency inverters that convert alternating voltage to an output normally given in 120/127 or 220V, and a frequency rate of 50 or 60 Hz (GUIMARÃES, 2012), discarding the use of elements to store the electricity produced. The production is interconnected to the electricity grid of the concessionaire, working as the storage element, because all generated energy is placed in parallel with the energy of the network. (URBANETZ, 2010).

The meter must be bi-directional with double operation. It must at least differentiate the active electrical energy consumed from the active electric energy injected into the network. (ANEEL, NT 0129/2012).



Fig. 2: Residential SFCR
Source: Solar Portal

Spreadsheet 1- List of materials used in the SFCR installation.

BLACK SOLAR CABLE WITH 4.0MM ² UV PROTECTION
RED SOLAR CABLE WITH 4.0MM ² UV PROTECTION
VD/AM SOLAR CABLE WITH UV PROTECTION 6.0MM ²
CONNECTOR MC4 FEMALE 4-6MM ² (12-10AWG)
CONNECTOR MC4 MALE 4-6MM ² (12-10AWG)
INTER KLAMP 40MM KIT (INTERMEDIATE CLAMP)
END KLAMP 40MM KIT (TERMINATOR CLAMP)
STEEL HOOK KIT
ALUMINUM PROFILE CLUTTER GS
GROUND CLAMP
WIRE CLAMP
GROUND JUMPER
GROUND CLIP
ANODIZED ALUMINUM PROFILE FOR PV MODULES (4,20M) GS
STB02-1000V / 01, STRING BOX DC + AC
PHB5000D-NS, PHOTOVOLTAIC INVERTER – wifi
325WP PHOTOVOLTAIC MODULE; (JKM325PP-72-V) JINKO (brand)

With the definition of the monthly average consumption and the production achieved with the implementation of the system during the whole year, in the most favorable periods of irradiation and in rain periods, it was performed a comparison and an analysis of the investment for the implantation of the new technology of energy production from these tabulated data.

For the tabulation and analysis of the found data, the Microsoft Office Excel tool was used. The project parameters are in accordance with RN N ° 482 of April 17, 2012 (ANEEL), which regulates all mini and micro generation of solar energy, ABNT NBR 11704 -

Photovoltaic Systems-Classification: this standard classifies the systems photovoltaic conversion from solar to electric.

III. RESULTS

For the presentation of the results, a case study was performed in a residence that installed a Grid Tie photovoltaic generator system of 10.40 kWp, with an average generation estimate of 1600 kWh per month. The article presents a model capable of supplying the energy demand for a residence of 50 m² where a traditional Brazilian family of four people resides.

The sizing of the electric energy consumption is based on the quantity of electric appliances and their power (Table 1).

Table.1: Household appliances in a 50 m² house, where a typical Brazilian family of four middle class people lives.

Appliance Quantity	Power (W)	Usage Time (h)	Daily Consumption (E = P * Δt)
Lamps – 6	60*6= 360	6	2160
Electric Shower – 1	4500	0,5	2250
Air Conditioning – 1	1800	6	10800
Television – 1	200	8	1600
Radio 1	50	4	200
Refrigerator – 1	200	24	4800
Iron – 1	500	0,5	250
Receptor TV – 1	20-55 = 31,66	24	759,84

Computer – 1	250	4	1000
Washing Machine – 1	1500	0,5	750
Microwave – 1	1300	0,5	650
TOTAL			25.219,84

In 30 days the consumption will be,

$$25.219,84 * 30 = 756,595 \text{ Wh or } 756,595 \text{ kWh}$$

Therefore, the monthly consumption of the residence is 756,595 kWh;

The system introduced to generate 1600 kWh in the analyzed residence is composed of:

- 32 Photovoltaic Modules 325 WP; (JKM325PP-72-V) Jinko;
- 02 Photovoltaic Inverters PHB5000D-NS -Wi-fi;

Table.2: Generation of Electric Energy by the photovoltaic generator system Grid Tie 10.4 kWp installed in the last 4 months.

Month	Generation (kWh)	Qty. Active Days (d)	Daily Average (kwh / d)
February	981,5	23	42,67 kWh
March	1.119,5	27	41,46 kWh
April	1179,3	30	39,31 kWh
May	601,5	15	40,1 kWh

The system has been working from February until now in a rainy season that did not provide its maximum generation capacity due to climatic conditions, not allowing high solar irradiance rates that are directly linked to SFCR energy production (Table 3).

Table.3: Solar Irradiation in the Horizontal Plan of the last 12 months

Latitude: 10,5° S
Longitude: 48,417206° O

#	Estação	Município	UF	País	Irradiação solar diária média [kWh/m ² .dia]												Média	Delta				
					Latitude [°]	Longitude [°]	Distância [km]	Jan	Fev	Mar	Abr	Mai	Jun	Jul	Ago	Set			Out	Nov	Dez	
✓	Porto Nacional	Porto Nacional	TO	BRASIL	10,501° S	48,449° O		3,5	5,20	5,23	4,91	5,05	5,10	4,95	5,05	5,82	5,76	5,43	5,13	5,14	5,23	,91
✓	Porto Nacional	Porto Nacional	TO	BRASIL	10,501° S	48,349° O		7,5	5,20	5,25	4,88	5,01	5,03	5,01	5,18	5,85	5,73	5,45	5,22	5,18	5,25	,97
✓	Porto Nacional	Porto Nacional	TO	BRASIL	10,4° S	48,449° O		11,7	5,16	5,21	4,91	5,05	5,08	4,91	5,04	5,74	5,76	5,44	5,15	5,11	5,21	,86

Irradiação Solar no Plano Horizontal para Localidades próximas



It is possible to verify that in these last months in the raining season the solar irradiation presented lower values due to the climatic conditions of this time of the year, affecting the generation of energy. Even though the system was able to supply the demand for the building and also generate credits in the concessionaire. These credits can be used for the next 5 years (60 months).

The cost-benefit of the SFCR implementation is made by analyzing the last 12 months of consumption and the value of the energy bill of the building analyzed to understand the economy achieved immediately (Table 4).

Table 4 – Energy bill history of the Consumer Unit analyzed in the last 12 months.

Year	Month	Reading Date	Consumption	Value (R\$)
2018	April	04/24/2018	100	238,51
2018	March	03/23/2018	100	231,06
2018	February	02/22/2018	191	290,45
2018	January	01/23/2018	1066	900,83
2017	December	12/22/2017	861	808,04
2017	November	11/23/2017	894	886,27
2017	October	10/25/2017	1129	1.056,79
2017	September	09/25/2017	1212	1.094,10
2017	August	08/24/2017	1001	937,24
2017	July	07/25/2017	842	743,02
2017	June	06/26/2017	1199	1024,85
2017	May	05/24/2017	1150	1.038,65

The last 03 months already presented much smaller values than the previous ones, thus showing the economy achieved with the implantation of the system, but to measure the true gain with this implantation it is necessary to take into account the initial installation cost of this system that fits the design, material and manpower. The SFCR of 10.40 kWp installed in the residence had a cost of R\$ 42,000.00 with freight included.

Using the invoice values between May 2017 and January 2018 we have an energy cost average value of R\$ 943.31, considering the values of March and April/2018. With the system in operation, this average decreases to R\$ 234.78,

with a total decrease value of R\$ 708.53. This difference is almost equivalent to the value of the system's financing parcel that revolves around R\$ 740.00, divided in 60 months.

The installed system of 10.4 kWp, with a power generation estimative of 1600 kWh, has a cost of R\$ 42,000.00 according to the project of the MVC projects and solutions. For a residence of 50 m², a system is expected to generate 800 kWp, thus supplying the energy demand of the residence (Table 5).

Table 5 - Estimated value of SFCR implantation for a 50m² building in Tocantins according to the equipment capacity.

System	Estimate d Generation	Converter	Photovoltaic Molde	Value
GT 10,4 kWp	1600 kWh	2 un - PHB 5000	32 Plates Jinko	R\$ 42.000,00
GT 5,2 kWp	800 kWh	1 un - PHB 5000	16 Plates Jinko	R\$ 21.000,00 *

* in the presented values are included: design, installation, material and freight.

Calculation of Return on Investment:

System implementation value: R\$ 42,000.00;

Average amount of energy bill (without the system): R\$ 943.31;

Average amount of energy bill (with the system): R\$ 234.78;

$$234,78x + 42000 = 943,31x$$

$$943,31x - 234,78x = 42000$$

$$708,53x = 42000$$

$$X = 42000/708,53$$

$$X = 59,27 > X = 60 \text{ months to return - 05 years;}$$

The tropical climate with the high incidence of solar rays is constant during the most part of the year in the North region of the country where Tocantins is located. The localization of the state is right inside the Brazilian solar belt, and the intensity of solar irradiation in the state of Tocantins tends to remain high between the months of June and January, promoting high rates of ES generation and even with the presence of rain from February to May the generation of energy continues to occur even on a smaller scale, but still the necessary amount for the demand of the building.

IV. CONCLUSION

The implementation of this efficient method of energy generation that is still little used by society means that the building can generate the necessary energy charge for its operation. The system presents a low weight and does not

require reinforcement of the roof structure and for being compact it is suitable on the roof of any residence.

The initial investment of the ES system is diluted in its financing installments. This option is feasible, as the banks offer credit lines to initiatives aimed at the sustainable development of the planet for the next generations, and this type of energy, which is considered clean, does not produce elements that attack the environment other than thermoelectric and nuclear, and do not promote sudden changes in a natural space such as hydroelectric. This type of energy is produced from the absorption of the natural element, in this case being solar irradiation, without harming the environment.

The photovoltaic power system is interconnected to the distribution network, launching energy production directly into the grid and calculating this consumption and production through the bidirectional meter, so that surplus storage stored by the utility can be used by the owner for the next 60 months, thus allowing that even when energy production is lower than consumption because of unfavorable climatic conditions the value remains the minimum at the end of the month.

The results presented the initial investment for the execution of the project and simulated the return of this invested capital in almost 60 months, which means that in 5 years of operation the economy generated in the energy bill is equivalent to the amount applied in the system, and since the SFCR has a useful life of 25 years, the remaining 20 years have a savings of about 75% per month in the invoice amount.

The use of the SFCR as an option for direct generation brings several points that indicate the positivity of its implementation, because the power output is close to where it will be built, thus promoting the global reduction of losses and possible reduction of the need for new transmission lines and distribution. The flexibility of implementation in a short time is another positive point, in addition to providing a modular approach to problems addressing particular demands with specific solutions. The independence of the system installation allows the reduction of the grid load, greater operational flexibility and better voltage profile that allows the application of different demand management techniques.

And so we conclude that after the analysis of the parameters of the Tocantins state for a family residing in a house of 50sqm, that in the short term the implantation of the system generates a relatively high cost, but that can be attenuated with the installment of this investment. In the medium term, considering its 25 year lifespan, the return by the mark of 5 years is considered fast. In the long term we have a satisfactory result, with 20 years of energy savings, being only willing to pay taxes like street lighting and taxes embedded in the invoice.

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