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Comparative study of the costs of implementation of three types of photovoltaic energy systems in the city of Porto Nacional - TO

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***Abstract*—*It is known that the world is at a time when society is increasingly seeking to adapt to the means of sustainable development as a way of preserving the environment and maintaining balance so that there is no depletion of the energy resources present in the world. One of these means is solar or photovoltaic energy, which is based on the conversion of energy that is radiated by the sun into electrical energy by means of photovoltaic cells, distributed in panels that are part of the photovoltaic generation system. The present work aims to carry out a comparative study of the cost of implantation of the solar energy system with methods of structures with active, chronological and sensor trackers. Implementation costs were assessed, in addition to identifying the efficiency of each system along with advantages and disadvantages.*

I. INTRODUCTION

Solar energy is a type of renewable energy that is obtained through the sun and can be used as a source of electrical energy or even for heating water. Its use has been growing all over the world because it is one of the cleanest forms of energy production. It is used in various media and different technologies that are constantly changing, among them are solar heating, solar photovoltaic energy, hydrothermal energy, solar architecture and artificial photosynthesis.

The conversion of solar energy into electrical energy takes place through the photovoltaic effect process (*Photo* which) using a surface that is composed of a semiconductor material that has the name of a photovoltaic panel. The electrical voltage that occurs is caused by the excitation of electrons in the semiconductor material due to the incidence of photons that are components of solar radiation.

With each passing day, the human being has been looking for renewable means to maintain himself without harming the environment so much, and with that the solar energy trade is growing all over the world. Therefore, the business of this type of material grows with several options.

There are panels with trackers and those that are fixed. The tracking types seek the energy that comes from the sun by tracking its movement and thus capturing a greater amount of it, since it is always towards the sun. The fixed type is only in one position to capture the energy.

The present work aimed to assess the costs of implementing three types of solar energy system, being active, which guides the panels towards the maximum light intensity, by sensors, which work under the principle of the difference in lighting and the chronological, which is based on date and time, also verifying the efficiency of each one of them and their advantages and disadvantages in relation to maintenance costs in the medium and long term.

II. TEORETICAL FRAMEWORK

SOLAR ENERGY

Photovoltaic solar energy is obtained by converting solar radiation into electricity using semiconductor materials. This phenomenon is known as the Photovoltaic Effect (BRAGA 2008).

He knows that this effect was first explored in 1839, by the Frenchman Edmund Becquerel, in a solution of selenium. He observed the appearance of a solution between the conductive solution electrodes, whenever it was illuminated by sunlight. In 1870, this effect was studied in solids and in the middle of 1880 the first photovoltaic cell was built using selenium.

SOLAR ENERGY IN THE WORLD

The main branches of use of solar energy internationally are for heating water and generating electricity under photovoltaic effect.

Bandeira (2012) explains that regarding the application of solar energy to water heating, according to information from the Atlas of Electric Energy of Brazil - 3rd Edition 5, for a long time Israel was the only country to require a minimum participation of water heating from solar energy. As of 2006, Spain assumed a similar stance and began to require minimum levels of solar energy for both water heating and electricity generation in new constructions such as residential buildings, hotels and hospitals. In 2007, the initiative was followed by countries such as India, South Korea, China and Germany. The required percentages range from 30% to70%, depending on the climate, level of consumption and availability of other energy sources.

All the growth in installed heater capacity solar water and photovoltaic panels in the world is heavily subsidized. In the several countries where there is significant growth in the use of solar energy, both manufacturers and investors in equipment for capturing and converting solar energy have tax benefits and incentives in electricity tariffs(FLAG, 2012).

SOLAR ENERGY IN BRAZIL

As in other countries, in Brazil the main means of using solar energy are to heat water and to generate electricity through the photovoltaic effect.

According to Rella (2017), the installed capacity in Brazil, taking into account all types of plants that produce electricity, is in the order of 132 gigawatts (GW). Of this total, less than 0.0008% is produced with solar photovoltaic systems (they directly transform sunlight into electrical energy. Photovoltaic generation in the country is residual compared to other sources, such as wind.

According to the Energy Research Company - EPE, if Brazil took advantage of all the existing solar potential, there would be a production of 283.5 million MW per year of photovoltaic energy. Thus, this power wouldbe able to supply more than twice the current domestic consumption of 128.8 million MW per year in the country.

Brazil currently has more than 20,000 companies operating in the field of solar energy, according to Portal Solar. The sectors that stand out the most are equipment manufacturers and installation services for distributed generation, and the main companies are concentrated in the state of São Paulo.

According to the National Electricity Agency (ANEEL), the forecast is that, in the year 2024, the country will reach 886 thousand consumer units with a total installed power of 3,208 Mega Watts.

SOLAR ENERGY IN TOCANTINS

The use of solar energy in Tocantins increased by 30% in 2018, mainly during periods of drought. The installation of solar panels in the region helps residents to save on electricity costs, in addition to contributing to the environment that is already so devastated, further favoring the use of ecological means.

The state of Tocantins, according to the Atlas Solarimétrico, has high levels of solar incidence, which helps to directly contribute to the great efficiency of photovoltaic panels and the generation of clean and renewable energy. Thus, Tocantins is characterized as the state that has the best solar radiation in the northern region of Brazil, constantly increasing the development of the use of technology in homes and commerciale stablishments.

NBR 16690

NBR 16690 - Electrical installations for photovoltaic arrays - Design requirements - published on10/03/2019, establishes the design requirements for electrical installations for photovoltaic arrays, also includes the provisions on conductors, electrical protection devices, switching devices, grounding and equipotentialization of the entire photovoltaic arrangement. It includes all parts of the photovoltaic array up to energy storage devices, power conditioning units or loads.

BOARDS WITH ACTIVE TRACKERS

According to Queirozet al. (2018), active tracking systems have a set of motors and sensors that are capable of orienting the panels towards the maximum light intensity. How electricity production is directly related to the incidence of energy light, active tracking improves system efficiency. They are usually based on a pair of photosensitive elements capable of varying the level of some electrical quantity according to the incident light radiation.

The active type tracker includes the use of one or more electric motors in each of the tracking axes of the mechanical support of the photovoltaic modules. The motors are controlled by means of an electronic circuit that receives data from the position of the sun through sensors (MONTEIRO, 2007).

Active solar trackers can track the sun on one or two axes. The one-axis tracker has a single axis in the North-South direction, around which the photovoltaic array rotates to align with the sun throughout the day. In the case of the two-axis tracker, there is also a second axis in the East-West direction that allows the arrangement to adjust its inclination to suit the different inclinations of the sun throughout the seasons (OLIVEIRA, 2007)

PLATES WITH SENSORS AND CHRONOLOGICAL TRACKERS

The main feature of the tracking strategy based on micro controlled optical-electric sensors is the use of a processing unit and at least two optical sensor units, which work under the principle of difference in illumination. The tracking strategy based on date and time is characterized by the use of formulas and algorithms sensors, geographic location as well as local time, as inputs to the controller, which generates signals for the system's guidance mechanisms (QUEIROZ et al., 2018).

Chronological trackers rotate according to the apparent speed of the sun. The revolution of the sun is 360 ° in 24 hours, so the structure of the panel must rotate at a speed of 15 ° / h during the period of sunshine. Therefore, this form of tracking can receive the location information as parameters and perform the calculation ofthe positioning of the sun in its code and send a control signal for the engines to actuate (GODOY, 2019)

SOLAR LOCATORS

The solar tracking system needs locators to work. As a type of locators, we have the physical, hybrid and software locators.

Physical locators are devices that have sensors that can read the solar location and thus transmit this data so that the panel can be located. Its greatest benefit is the ease of implementation of the system, and its disadvantage is that it is only valid at times when the sun is not covered.

The software locators are equipment that can be programmed to perform the movement of the panel to a certain position, the panel will have a certain position at a certain time of the day, this movement is already pre-established for all changes in the sun both in the daily as annual period. Its greatest benefit is the possibility of using it even with the sun overcast, since the panel will continue its automatic path, since its obstacle would be the cost of implementation due to the complex programming that involves it. The main equipment that can perform this routine are micro controllers, PLCs and microcomputers. And the hybrid locators are those that move through software and hardware, with the advantage of the system's credibility, since even with weather-related setbacks, it continues to move. As a disadvantage, it has the high cost of implementation, since sensors and microcontrollers need to be implanted (KUHN, 2013, page 30).

MAINTENANCE OF THE MODULES

Maintenance is the set of actions responsible for keeping the mechanisms in operation, these actions involve conservation, adequacy, restoration, replacement and prevention. Without a good maintenance program, the losses caused by defective equipment are high due to delays or interruptions in production, which can cause market loss due to customer dissatisfaction (CARMO, 2019).

According to Greco (2006), the maintenance activity needs to be efficient and effective; that is, it is not enough to just repair the equipment or installation as quickly as possible. It is necessary to maintain the function of the equipment available for operation, avoid equipment failure and reduce the risks of an unplanned production stoppage.

Maintenance can be divided into two groups that are separated into scheduled and unscheduled maintenance.

Unscheduled maintenance, also known as corrective maintenance, is one in which a repair or replacement of a part is carried out due to the occurrence of an unforeseen failure. This type of maintenance is practiced only after the equipment or the machine is damaged. Corrective maintenance is not recommended as the main maintenance strategy. Preventive maintenance consists of a set of procedures and early actions that aim to keep the machine running. It is assumed that the maintenance service can be planned in terms of number of hours of machine operation or even a total elapsed time, in hours, year, cycles, mileage traveled, capacity produced among others. The main advantages of this type of maintenance are the lower occurrence of sudden breaks and the fact that the stops are planned. On the other hand, unnecessary work may occur and defects still occur once the maintenance program takes into account only the average conditions of the plant's equipment, based on the manufacturer's history and / or recommendation (CARMO, 2019, page 19).

ECONOMIC FEASIBILIT

According to CARMO (2019), for an economic feasibility analysis of the solar tracking system, thegain in energy generation obtained from the use of the solar tracking system is converted into a monetary value.Concomitant to this, maintenance costs are also estimated. With this data, it is possible to determine the paybackperiod for the investment or Payback.

Payback is not always the most used tool for decision making, however it is a technique that can beused in the evaluation of investment in view of cash flow over time. The recovery period is the time that theinvestment takes to be recovered according to the discounted cash flow. Based on the assumption of these data, itis possible to infer about the economical viability of the solar tracking system.

III. MATERIAL END METHOD

The costs of implementing the fixed system and the system with solar energy trackers were measured, being active, by sensors and the chronological through surveys in the solar energy companies in the city of Porto Nacional and region using the connection method phone and email.

The collection of data to compare the costs of implementing solar systems occurred in the months of March and April of the year 2021. The budgets were made in two companies. The costs of the fixed system were measured at the company Portal Solar and the costs of the system with trackers were researched at the company Ourolux Solar.

In the beginning, it would be necessary to define the average powers in order to continue with the budget, and thus the powers of 500, 1500 and 3000 KWh / month were chosen. Thereafter, the costs of materials were requested along with the installation for each of the two selected companies. The basis of comparison was in soil structure, since it is closest to all the models that will be analyzed.

IV. RESULTS END DISCUSSION

The company Portal Solar, made available the budget with the cash price and financed. It also contains the number of panels required for the power and minimum area required for their installation. Ouroluxdoes not provide the installation, only the equipment.

Table.1: Fixed solar system budget for an average monthly production of 500 kWh

FIXED SOLAR SYSTEM	
MONTHLY PRODUCTION	500 KWh / month
INSTALLED POWER	4.1 KWp
MINIMUM AREA REQUIRED	32.8 m²
QUANTITY OF PANELS	10 of 405 W
SUMMARY VALUE	24,127.09 reais
FINANCED AMOUNT	72x from 586.77 reais

Table.2: Fixed solar system budget for an average monthly production of 1500 kWh

FIXED SOLAR SYSTEM	
MONTHLY PRODUCTION	1500 KWh / month
INSTALLED POWER	11.3 KWp
MINIMUM AREA REQUIRED	90.4 m²
QUANTITY OF PANELS	28 of 405 W
SUMMARY VALUE	51417.23 reais
FINANCED AMOUNT	72x from 1250.47 real

Table.3: Fixed solar system budget for an average monthly production of 3000 kWh

FIXED SOLAR SYSTEM	
MONTHLY PRODUCTION	3000 KWh / month
INSTALLED POWER	23.5 KWp
MINIMUM AREA REQUIRED	188 m²
QUANTITY OF PANELS	58 of 405 W
SUMMARY VALUE	24,127.09 reais
FINANCED AMOUNT	72x from 2497.88 reais

The company Ourolux solar, when providing the cost estimate of the system with trackers, also provided the value of the freight. This budget does not include the installation, only the material. The form of payment provided by the company is only anticipated. All systems are connected to the network, better known as On Grid and their monitoring is done via the software of each inverter.

Table.4: Solar system budget with trackers for average monthly production of 500 kWh

SOLAR SYSTEM WITH MONTHLY	
PRODUCTION TRACKERS	500 KWh / month
VALUE MATERIALS	R $ 12376,77
FREIGHT AMOUNT	R $ 618.84

TOTAL	R $ 12,995.61

Table.5: Solar system budget with trackers for average monthly production of 1500 kWh

SOLAR SYSTEM WITH MONTHLY	
PRODUCTION TRACKERS	1500 KWh / month
VALUE MATERIALS	R $ 45928.88
FREIGHT AMOUNT	R $ 2296.44
TOTAL	R $ 48225.32

Table.6: Solar system budget with trackers for average monthly production of 3000 kWh

SOLAR SYSTEM WITH MONTHLY	
PRODUCTION TRACKERS	3000 KWh / month
VALUE MATERIALS	R $ 91857.76
FREIGHT AMOUNT	R $ 4592.88
TOTAL	R $ 96450,64

V. CONCLUSION

According to the results of the cost estimates for the implementation of solar systems, to install in the city of Porto Nacional - TO, it can be observed that the values are different and despite the solar system with tracker, regardless of its type, to capture more energy due to the advantages of following the maximum solar luminosity, it is always important to see the economic viability of each citizen when choosing which system to use. The fixed system in the company in which the budget was made, already comes with the value of incuse labor, and this adds up in the choice of who chooses this type of system. Depending on how complex the system is, deployment costs are higher.

When it comes to the advantages and disadvantages of the fixed system and the system with trackers, it is possible to say that the fixed system has a lower cost when compared to the system with a tracker but in return, it captures less amount of sunlight to be converted into energy., since it is only in one direction. The system that has a tracker, has a higher cost due to the fact that it needs more software and equipment, but with that it can capture more heat stroke, because it can follow the direction of the sun.

Brazil receives a large amount of heat stroke per year. Only in the Northeast, the average daily solar incidence varies between 4.5 to 6 KWh. Based on these data, it is possible to observe that Brazil has an abundant energy source, but ends up taking little advantage of this great potential and with unique characteristics that the country has.

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