ISSN: 2639-7455

Research article

Earth & Environmental Science Research & Reviews

Proposal of A Photovoltaic System at Sagua of Tánamo´S Municipality

Alvaro Laurencio Pérez[1], Igor R. Pérez Maliuk[2], Olga Pérez Maliuk[1]

[1]*(Moa University)*

[2]*(Electric Company)*

[*]Corresponding author
Alvaro Laurencio Pérez, Moa University

Submitted: 19 Nov 2020; **Accepted**: 27 Nov 2020; **Published**: 06 Dec 2020

Abstract

The increasing use of electrical energy drawsthe attention of scientists around the world to studies of alternatives for the generation of electricity through renewable energy sources, among them, photovoltaic solar energy. This work proposes a photovoltaic system connected to the grid for the town of Sagua. The PVSyst software was used to calculate the energy production of the photovoltaic system and the economic evaluation criteria Net Present Value, Internal Rate of Return and Payback Period to verify its profitability. The proposal resulted from a 3.28 MW capacity site, from which 4407 MWh/year is generated, for a payback period of 5 years. The proposal made establishes that it is feasible to start up a 3.28 MW installation in this area from a technical and economic point of view.

Keywords: Energy, Irradiation, Photovoltaic System.

INTRODUCTION

Currently, the energy matrix worldwide is based on fossil fuels and the rate of consumption is accelerated, so that the depletion of existing reserves is a reality. The growing use of electricity makes it necessary to study alternatives for generating electricity through renewable energy sources, including photovoltaic solar energy. For this reason, strategies for the use of these are implemented in different sectors of the economy around the world [1, 2].

Within the guidelines of the economic and social policy approved in the VI congress, the Communist Party of Cuba alludes to the use of alternative sources of energy in guideline 247, in which it is proposed to promote the use of different renewable sources of energy, prioritizing those that have the greatest economic effect. Which leads to several investigations to be based on it [3, 4].

The growing demand for energy and the energy context in which the country finds itself require the use of alternative sources, among these, renewable energy sources through photovoltaic systems.

In order to encourage the use of photovoltaic solar energy, various countries have implemented economic strategies that contemplate the initial financing of projects. According to some research, in recent years, the cost of the installed kW of photovoltaic energy has reduced its value, this offers better results in economic feasibility studies related to the subject [5, 6]. The literature consulted is based on performance studies, as well as technical-economic studies and proposals for the installation of photovoltaic systems [7-9].

The objective of this work is to make a proposal for a photovoltaic system connected to the grid in the town of Sagua de Tánamo belonging to the province of Holguín, using the PVSyst software to calculate the energy production of the proposed photovoltaic system and taking into account It takes into account the criteria of Net Present Value (NPV), Internal Rate of Return (IRR) and Payback Period (PR) for the economic evaluation of the proposal.

Materials and Methods

Characteristics of the area

The proposal is made in the Sagua de Tánamo municipality belonging to the Holguín province at coordinates 20.350 north latitude and -75.350 west longitude, occupying an area of 19891.32 m^2 as shown in figure 1, obtained from the site www.googlearth .com.

Figure 1: Site location

The photovoltaic system is proposed to be connected to the 33 kV Moa - Sagua network that is fed by the O570 switch, with a total distance of 22 km according to the data provided by the Holguín provincial UEB.

Sizing and Photovoltaic Module

The proper design of a photovoltaic generation system will depend on the correct dimensioning of the elements that compose it and the factors that influence its operation. Mainly the space available to generate the greatest amount of electrical energy, taking advantage of the maximum surface and time of incidence of solar radiation in the solar modules [7].

The minimum distance between rows of the array of photovoltaic modules must also be taken into account, since this distance marks the limit reached by the shadow caused by the front row of the arrangement [10].

PVSyst software

The PVSyst software is a tool used to model the behavior of photovoltaic installations; allows the study, simulation and data analysis of photovoltaic systems. With this software, facilities can be dimensioned, taking into account the solar radiation that it would receive depending on its location thanks to its meteorological database, and which takes into account the projection of shadows thanks to the simulation of the movement of the Sun during the day [11]. This software constitutes the calculation tool for estimating the production of the proposed photovoltaic system.

The proposal is made with photovoltaic modules manufactured in the province of Pinar del Río, from the series DSM-270. The characteristics of the same, as well as the technical data are shown in the Table 1.

Table 1: Features and technical specifications of the DSM - 270 series

Especificaciones técnicas	
Celda	Celda Solar de Silicio Multicristalino
	156,75mm x 156,75mm
No. De celdas y conexiones	60 (6x10)
Dimensiones del módulo	1650mm x 990mm x 40mm
Cubierta frontal	Vidrio templado
Material del marco	Aleación de aluminio anodizado
Peso	18,1
Características eléctricas	
Modelos	DSM-270
Voltaje a circuito abierto	38,0
Voltaje en el punto de máxima potencia	32,1
Corriente de corto circuito	9,11
Corriente en el punto de máxima potencia	8,42
Potencia máxima a STC	270
Tolerancia	± 3

Methods for Economic Evaluation

Currently, the criterion for selecting the technical solution is its economic utility, so that, to accept a proposal, an economic study must be carried out to guarantee that the project is profitable. Among the criteria most used by the consulted literature are the Net Present Value (NPV), the Internal Rate of Return (IRR) and the Payback Period (PR). The NPV measures in current money the degree of greater wealth that the investor will have in the future if he undertakes the project. It is defined as the updated value of the flow of net income obtained during the economic useful life of the project from the determination by year of the inflows and outflows of cash, from when the first investment expense is incurred during the investment process until the years of operation or functioning of the project less the initial investment [2, 7, 11]. According to [2], the NPV can be obtained by the equation (1)

$$VAN = -I_0 + \frac{FC_n}{(1+k)^n}$$

where: I_0 is the initial investment; *FCn* is the cash flow for year *n;* *k* is the discount or interest rate and n is the number of the year.

The internal rate of return is the discount rate that equals the present value of the cash flows with the investment of the project, it is the rate that makes the NPV zero [12]. Its use is considered advisable if the resulting IRR is equal to or greater than the rate required by the investor.

This method consists of an iteration process where two NPVs are searched, one positive and one negative, whose values are the closest possible to zero. Once the positive and negative values with their corresponding interest rate have been found, the equation (2).

$$TIR = k_p + \left[(k_n - k_p) \cdot \frac{VAN_p}{(VAN_p - VAN_n)} \right]$$

where: *kp* and *kn* are the interest rates at which the positive and negative *NPV* values are obtained; the *NPVp* and *NPVn* are the positive and negative Net Present Value, respectively.

The payback period marks the time, in years, that the project costs are supplemented by the benefits achieved. In other words, it is the expected number of years it takes for an investment to pay off. In [2] an equation is presented to calculate it, however, when the cash flows are constant and the duration of the investment is finite, its determination is obtained from the mathematical expression (3).

$$PR = \frac{I_0}{FC}$$

where: the *CF* is the annual cash flow.

Indentations and Equations

This section presents the results obtained from the study.

Angle of Inclination and Arrangement of the Assembly

For the simulation, the angles from 15 to 220 are taken into account, in which it is more profitable to use 180 for the inclination of the photovoltaic modules, taking into account the energy values generated in the year, as shown in figure 2.

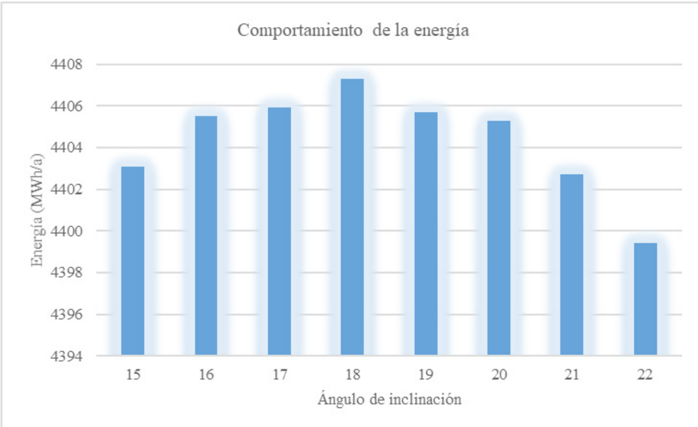

Figure 2: Annual energy production according to the inclination of the photovoltaic modules

The results show that a 3.285 MW photovoltaic system with a total of 12166 photovoltaic modules can be implemented on an area of 19891.32 m^2.

Table 2: Characteristics of the photovoltaic set

Elementos del conjunto	Cantidad
No. de módulos total	12166
No. de módulos serie	14
No. de módulos paralelo	869
No. de Inversores	5 de 0.5 MW
Potencia instalada	3.285 MW

For this arrangement, it is determined that 5 inverters of 0.5 MW with a voltage range of 310 - 480 V.

Performance Ratio and Energy to Be Delivered to The Grid

The performance index or Performan Ratio (PR) of the photovoltaic system by months is shown in figure 3.

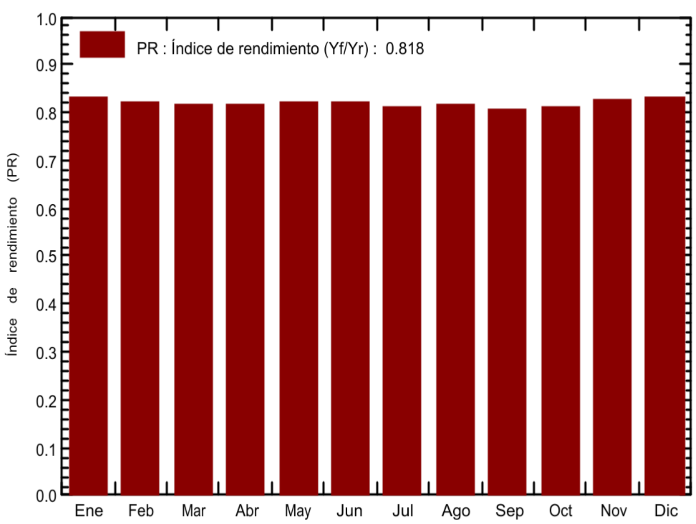

Figure 3: Performance index by months

Figure 3 shows that the PR behaves almost invariably throughout the year, reaching values of up to 0.832 in the month of December and averaging 0.818 per year.

Figure 4 shows the loss diagram of the photovoltaic assembly throughout the year, in which the irradiation of the area is presented and the part of it that is lost until reaching the photovoltaic system. On the other hand, there is the energy that reaches the site, in the form of solar radiation, which is converted by it into electrical energy, which passes through a group of elements in which a certain part of said energy remains until finally the energy to be delivered to the system will be 4407 MWh per year.

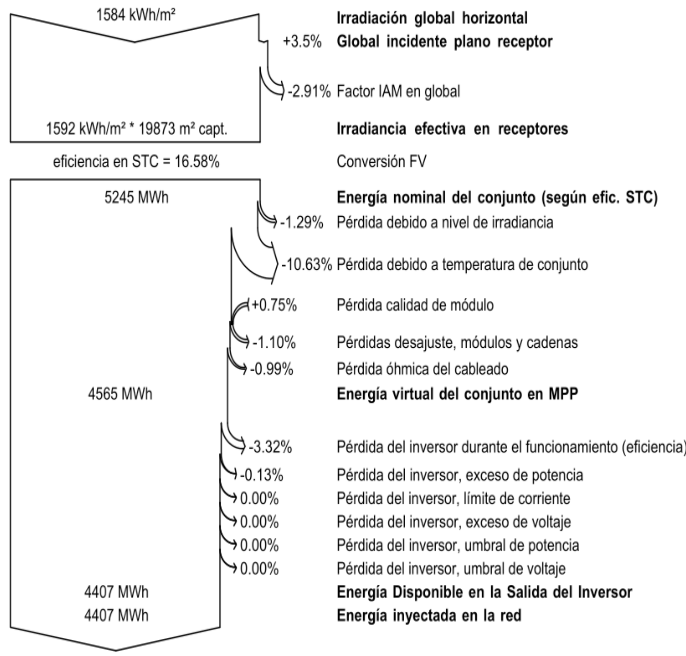

Figure 4: Energy diagram

Economic Evaluation

The economic evaluation starts from the initial investment of the study. Table 3 shows the elements to consider to determine the initial investment of the proposal.

Table 3: Cost of the elements to consider of the photovoltaic system

Elementos	Costo (USD)
Módulos	3284820
Inversores	14000
Transformadores	16500
Conductores	25000
Pernos para anclaje	3400
Base de hormigón	85000
Total	3428720

The proposal considers an initial investment of approximately USD 3.4 million.

Taking into account an energy cost of 150 USD/MWh, the cash flow per year is equivalent to 661,050 USD/year, considering the resulting energy of 4407 MWh/year to be delivered to the grid.

Figure 5 shows the behavior of cash flow and accumulated cash flow from year zero to the 25-year useful life guaranteed by the manufacturer.

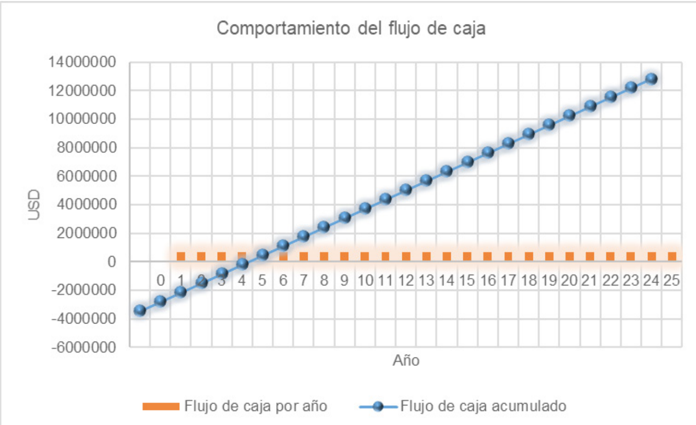

Figure 5: Behavior of cash flow by year

The accumulated cash flow per year is represented as a straight line, since the constant cash flow for each year is considered, since, unless an extraordinary event occurs, the energy produced each year is approximately the same.

From the calculations and figure 5 itself, it can be seen that the investment payback period is approximately 5 years, an admissible value, considering that the useful life of the photovoltaic modules is 25 years.

On the other hand, based on the initial investment value, the cash flow obtained and considering an interest rate of 12%, the NPV is 8572360.06 USD, so the project is profitable.

The IRR, for its part, is 17.7%, a value higher than the expected rate of 12%, which indicates that the project can be accepted based on this criterion.

Conclusions

- The chosen area has the conditions, from the point of view of solar radiation of the territory, to establish a photovoltaic system.
- The proposal made establishes that it is feasible to start up a 3.28 MW installation in the area from a technical and economic point of view.
- The initial investment of the proposed installation of a 3.28 MW photovoltaic system in the territory can be recovered in 5 years, a value that corresponds to 1/5 of the useful life of the photovoltaic modules.
- The angle of inclination of the modules for the Sagua de Tánamo region is 180.

References

1. Ospino A J C (2010) "Análisis del potencial energético solar en la región caribe para el diseño de un sistema fotovoltaico ". Inge-CUC, 6: 95-102.
2. Salas Y R, Gómez H B, et al. (2018) "Diseño técnico y económico de un banco de prueba solar fotovoltaico para generación de energía eléctrica de forma aislada". Prospectiva, 16: 82-88.
3. Guzmán M V, Soto C R C, et al. (2017) "Procedimiento para instalación de un sistema fotovoltaico sobre techos en la corporación cuba ron S.A". Centro Azúcar, 44: 70-81.
4. Ospino A C, Robles C A y, Duran A P (2014) "Modelado y simulación de un panel fotovoltaico empleando técnicas de inteligencia artificial". Ingeniería Energética, 35: 225-233.
5. Rodríguez A K M, Cadena Á I M, Aristizábal A J C (2015) "Diseño de sistemas de energía solar fotovoltaica para usuarios residenciales en Chía, Cundinamarca". Mutis, 5: 55-65.
6. Rubio E H C, Ordoñez L C L, Luis J Ricalde Castellanos, Emmanuel de la Cruz May, Ricardo J. Peón Escalante, et al. (2016) "Diseño de una micro red eléctrica inteligente con sistema fotovoltaico y celda de combustible" 120: 516-532.
7. González C L, Torres J, et al. (2018) "Estudio técnico económico de paneles solares interconectados a la red de distribución". Revista Iberoamericana de Ciencias, 5: 95-105.
8. Osorio Laurencio L, Montero Laurencio R (2016) "Análisis energético de un sistema fotovoltaico integrado a una cubierta plana horizontal". Ingeniería Energética, 37: 45-54.
9. Varo D, Menéndez H F (2017) "Análisis del rendimiento de un sistema fotovoltaico conectado a red de 10 MW, excluyendo el efecto de la temperatura". Ciencia, Tecnología y Medio Ambiente.
10. Quiroz F I V, González J a R, et al. (2016) "Análisis del dimensionamiento y distribución de un sistema fotovoltaico con fines de investigación". Pistas Educativas.
11. García J E G, Sepúlveda S B M, Ferreira J J (2018) "Viabilidad técnico-económica de un sistema fotovoltaico en una planta de tratamiento de agua". INGE CUC, 14: 41-51.
12. Taco D, Gutiérrez M (2018) "Valoración de inversiones en proyectos no convencionales - Tasa interna de retorno versus Tasa interna de retorno modificada.". INNOVA, 3: 126-133.