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Design And Implementation Of A Solar Photovoltaic Plant To Power A House In The Non-Interconnected Areas Of The Municipality Of Manaure, Guajira

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Abstract

This paper presents the implementation of a solar photovoltaic plant as a solution to the interconnectivity problems in the communities surrounding the municipality of Manaure in the department of La Guajira. The design and subsequent implementation of the system is presented here. This proposed system provides electricity to a house located in one of the non-interconnected areas, being a solution to this problem.

The implemented system obeys with the standards established by the Colombian technical standard (in Spanish NTC) 2050 and electrical installation regulations (RETIE) for photovoltaic systems. This system was installed with two panels of 375W, a load ratio system and a inverter of 1kW, corresponding to the design.

Keywords: Energy storage, Photovoltaic solar energy, solar radiation; Interconnectivity.

1. Introduction

Climate change is a reality; greenhouse gas emissions and polluting residues from the burning of fossil fuels have greatly modified ecosystems due to the extraction and manipulation of natural resources and the high consumption of electrical energy currently in demand [1].

Most remote and isolated communities that are not connected to national electricity distribution networks use combustion engines to generate electricity. The electricity generated by these types of systems is more expensive in itself than large power generation plants and in addition, the transportation and environmental costs associated with this type of energy must be added [2].

Among the areas of difficult access are the indigenous communities belonging to the municipality of Manaure, in the department of La Guajira, which are located in the vicinity of the so-called middle and upper Guajira, and due to their geographic location are far from population centers, making their electrical interconnectivity economically unfeasible [3].

A possible solution for the non-interconnected zones (NIZ) is the development of photovoltaic solar energy, one of the alternatives to mitigate the damage caused by the exploitation of natural resources [4]. In this way, with the implementation of a solar photovoltaic plant, electric energy can be obtained in the NIZ, contributing to the reduction of the effects of climate change [5].

In the NIZ of the municipality of Manaure, a solar photovoltaic plant (PSFV) was implemented to power a family house (Figure 1), for which the scheme and calculation of each of the components of the solar plant was performed [6].

Figure 1. House of Wayú community in the NIZ of the municipality of Manaure.
Source: Author

This paper is organized as follows: section 1 presents the introduction, section 2 presents the calculations of each of the components of the solar photovoltaic plant for a day's autonomy of operation, then the results are presented and finally, conclusions are given.

2. Materials and methods

The following design is developed applying the law 1715 of 2014 that regulates the use, application and development of alternative energies in Colombia, likewise the technical standards NTC 2775, NTC 1736, NTC 2883.74, NTC 2959, NTC 5287, GTC 114 and NTC

2050, which regulate photovoltaic installations, were taken into account. The following are some calculations made for the implementation of the solar photovoltaic plant.

According to the study, it is established that the photovoltaic system to be installed should produce a minimum of 40 kWh/month in the month with less irradiation, this is located at the following coordinates: Latitude: N 11° 48' 0.846"; Longitude: W 72° 22' 0.615" as shown in Figure 2.

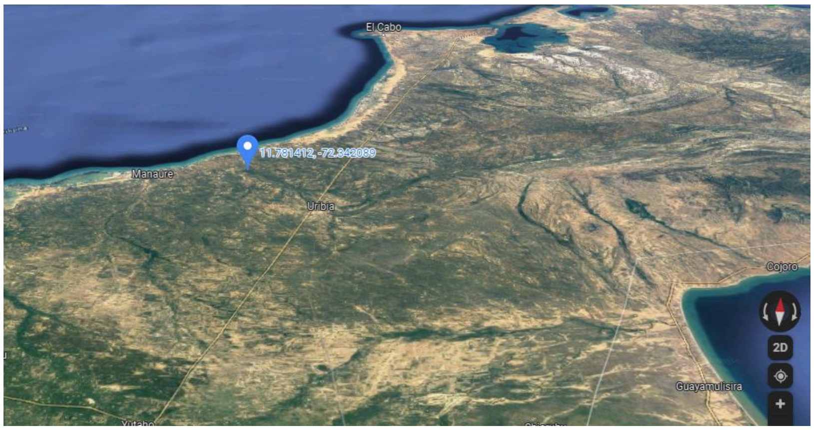

Figure 2. Geographical location of the site where the PSFV was implemented.
Source: Google Maps

According to the maps of Global Solar Radiation on a horizontal surface of the Solar Radiation Atlas of UPME and IDEAM, the daily average monthly flat solar radiation for the rural areas of Ciénaga, Magdalena is estimated, which are compared with those obtained from the meteorological stations, resulting in the values shown in Table 1, as shown below.

Table 1. Daily average monthly flat-plate solar radiation

Location	**I_{TH} (β=0,0)**	**I_{TH} (β =0,1)**	**I_{TH} (β =0,2)**	**I_{TH} (β =0,3)**	**I_{TH} (β =0,4)**
	Wh/m² día	**Wh/m² día**	**Wh/m² día**	**Wh/m² día**	**Wh/m² día**
Manaure	**6966,8**	**6713,4**	**6506,7**	**6338,3**	**6201,0**
Puerto Bolívar	**8212,8**	**7912,9**	**7668,6**	**7469,6**	**7307,5**
Nazaret	**6538,3**	**6303,1**	**6111,0**	**5954,2**	**5826,3**
Rancho Grande	**7853,9**	**7569,7**	**7337,9**	**7148,8**	**6994,6**

According to the data taken from IDEAM, the radiation is monthly, due to this, it is determined that April presents a lower radiation index with 5KWh/m^2 with a monthly energy of 40KWh and an energy factor of 1.16 [6]. We proceed to calculate the performance of the installation with Equation (1).

$$R = 1 - \left[(1 - b - c - v) \times a \times \frac{N}{Pd} \right] - b - c - v \qquad (1)$$

Where b is the coefficient of losses by the batteries, c is the coefficient of losses in the inverter, v is the coefficient of other losses in the installation, a is the coefficient of discharge of the batteries, N is the number of days of autonomy and Pd is the depth of discharge, obtaining a result of 0.6407.

Then, the energy required for the system is calculated taking into account the most critical month, Equation (2):

$$E = \frac{Et}{R}(Wh / dia) \qquad (2)$$

Where Et is the energy in the most critical month (April), obtaining a necessary energy of 4944.45Wh.

2.1. Solar Panels

Photovoltaic panels are devices that can transform solar energy into electrical energy, they consist of cells that operate according to the principle of the photoelectric effect [8].

To obtain the number of panels, according to the power required by the system, taking into account the following data obtained, as shown in Figure 3.

Tabla 2. System power variables.

Variables	**Value**
Solar declination (δ)	-23.371
Sunrise angle (Ws)	-86.419
Sunrise angle on an inclined plane (Wss)	-90.497
inclination of the site (β)	9.3731
eccentricity factor (Eo)	1.032
radiation on the horizontal plane (Hd,m(0))	81.55 Wh/m^2
clarity index (Ktm)	0.530
Diffuse fraction of radiation (Fdm)	0.40
Diffuse radiation (DdM(0))	1881.27 Wh/m^2
Radiation reaching the inclined plane (H)	2818.726 Wh/m^2
correction factor (K)	1.130
Direct radiation on the inclined plane (H(βα))	3185.391 Wh/m^2
Diffuse radiation on the inclined plane (D(βα))	1868.391 Wh/m^2

Dalbedo radiation on the inclined plane (A|(βα))	6.275 Wh/m^2
Total radiation on the inclined plane (G(βα))	5060.381 Wh/m^2
Solar peak hours (HPS(h))	5.060 horas
Peak power (Pp)	956.144 W

Source: Author

The following equation (3) allows to determine the required amount of solar panels that are necessary for the implementation of the system.

$$Np = \frac{Pp}{0{,}9 \times P_{\text{mod}\,ulo}} \qquad (3)$$

Where P_{modulo} = 375W; a required number of panels of 1,924 is found, approximating to 1 panels with a modulus of 375 W

2.2. Accumulators or Batteries

Batteries are the elements responsible for performing the function of storing energy when the photovoltaic production exceeds the demand of the application, to deliver it to the user in the form of direct current [7], [9]. This element turns out to be of great importance in the application of solar panels, due to its role mainly of accumulating energy and stabilizing the voltage of the respective installation [10], [11].

For the calculation of battery consumption, a discharge capacity of 75%, an autonomy of one day, a voltage of 12V and a temperature correction factor of 1 are taken into account, see Equation (4).

$$C_{ne} = \frac{E(L_{md)} * N}{P_{DE} * F_{CT}} \qquad (4)$$

Obtaining as a result a nominal capacity of the battery of 237,606Ah for which 1 battery of Gel of 250Ah to 12V was selected.

2.3. Regulator Dimensions

They are elements that allow to charge the batteries adequately and additionally avoid overcharging and excessive discharges of the batteries. Whenever batteries are used in a photovoltaic system, there must also be some kind of regulator to support the battery needs, see Equation (5).

$$I_{ent} = FS * I_{CS} * N_P \quad (5)$$

Panel short circuit current (SCC): 8.65 depending on the panel to be used.

Factor of safety (FS): 1.3

The following equations describe the incoming current (6), outgoing current (7), and the direct power of the inverter (8), which allows me to determine the proper operation of the system.

$$I_{ent} = 22{,}49A \quad (6)$$

$$I_{sal} = \frac{FS*(P_{DC}+\frac{P_{AC}}{\eta_{inv}})}{V_{Bat}} \quad (7)$$

Power in alternating current (PAC): 750Wh
Power in direct current (PDC): 0
Inverter efficiency (ηinv): 0.9

$$I_{sal} = 90{,}27A \quad (8)$$

2.4. Inverter Dimensions

Knowing that solar panels deliver direct or direct current, it is necessary to use inverters to convert the current, if required from direct or direct current (DC or DC) to alternating current, to feed some lighting points or household appliances, which necessarily work with alternating current [12], see Equation (9).

$$P_{inv} = FS * P_{AC} \quad (9)$$

Factor of safety (FS): 1.3. Equation (10).

$$P_{inv} = 975Watt \quad (10)$$

3. Results

According to the design and the data obtained, a solar photovoltaic system was installed in the house as shown in Figure 3.

Figure 3. Implementation of the PSFV.
Source: Author

This system consists of a regulator with a system for maximum utilization of the power supplied by the panel, as shown in Figure 4.

Figure 4. Implementation of the regulation stage.
Source: Author

Similarly, a 1000W inverter with an output voltage of 120Vac at 60Hz was implemented, which provides enough energy for the autonomous operation of the house as shown in Figure 4 and Figure 5 shows the installation of the panels and the respective inclination.

Figure 5. Installation of photovoltaic panels.
Source: Author

4. Conclusions

After inspecting the area, it was possible to identify and delimit the obstacles for the location of the solar panels, according to account the angles of radiation and geographic conditions. The on-site inspection was carried out since it is of vital importance to have a vision and dimensioning of the system to be implemented.

According to the standards and recommendations mentioned in the previous article and the topographic analysis, it was established that two photovoltaic panels of 375W each connected to a load control system that feeds a 1kW inverter were sufficient for the use of a rural house. The power generation systems with solar panels are presented as a solution to the problems of electrical connectivity of the NIZ of the Guajira region.

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