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Sizing of the photovoltaic system for a house located in the Presa la Concepción subdivision in Santiago Cuautlalpan, State of Mexico

Dimensionamiento del sistema fotovoltaico para una vivienda ubicada en el fraccionamiento Presa la Concepción en Santiago Cuautlalpan, Estado de México

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Abstract

To cover the needs of the human being, either electrical or thermal energy is used, which causes greenhouse gases due to the origin of the energy, since most of it is generated by burning fossil fuels. It is necessary to change the source of energy for others that are not polluting, that is, for renewable energies. In a house, energy consumption is in electrical appliances, lighting, air conditioning, entertainment equipment, stove and boyler. In a previous study, strategies were proposed for the passive air conditioning of a house in the Fraccionamiento de Presa la Concepción located in Santiago Cuautlalpan, State of Mexico, considering the bioclimate of the place. In the present study, the photovoltaic system required to cover the energy demand of that house is proposed. The characteristics of the home are briefly described (location, installed load and the bi-monthly consumption reported by CFE), the methodology to be followed for the sizing of the system and its application. A proposal of solar panels, inverter and battery to be used with their respective costs is given.

Photovoltaic, Energy saving, passive systems

Resumen

Para cubrir las necesidades del ser humano, se utiliza energía ya sea eléctrica o térmica, lo que ocasiona gases de efecto invernadero por el origen de la energía, ya que la mayor parte de ella se genera por quema de combustibles fósiles. Es necesario cambiar la fuente de energía por otras que no sean contaminantes, es decir, por las energías renovables. En una casa habitación, el consumo de energía está en los electrodomésticos, iluminación, aire acondicionado, equipos para diversión, estufa y boyler. En un estudio anterior, se propusieron estrategias para la climatización pasiva de una vivienda del Fraccionamiento de Presa la Concepción ubicado en Santiago Cuautlalpan, Estado de México, considerando el bioclima del lugar. En el presente estudio, se propone el sistema fotovoltaico requerido para cubrir la demanda energética de esa vivienda. Se describe brevemente las características de la vivienda (ubicación, carga instalada y el consumo bimestral reportado por CFE), la metodología a seguir para el dimensionamiento del sistema y su aplicación. Se da una propuesta de paneles solares, inversor y batería a emplear con sus respectivos costos.

Fotovoltaico, Ahorro de energía, Sistemas pasivos

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Introduction

The energy consumed in a house is usually thermal energy (used for food preparation or for heating water for bathing) or electrical energy (for household appliances and electronic devices), which are generated through fossil fuels, which, when burned, generate greenhouse gases that cause serious environmental pollution problems, such as global warming, climate change, changes in ocean currents, rising sea levels, etc. It is necessary to look for alternatives that allow us to cover our energy needs without causing problems to the environment.

The use of air conditioning systems are examples of energy consumption in homes, where not only the initial investment of the equipment is paid, but also the bimonthly consumption of the electricity bill. Hernández et al (2022) proposed strategies for the passive air conditioning of a house in the Presa la Concepción housing development located in Santiago Cuautlalpan, State of Mexico. With the data of the location of the house, the bioclimate of the place and the characteristics of the building envelope, they determined the temperature and hourly humidity tables of the place and established the thermal comfort zone. They determined the psychrometric process involved, the resulting heat balance due to sensible heat gains by occupants, equipment, solar radiation and environment, and finally, the air flow required by the equipment. They proposed strategies, considering thermal insulation, coatings and passive systems.

The present study, takes up the house located in the Presa la Concepción subdivision, to dimension a photovoltaic system that is capable of covering its electrical energy demand.

Location and climate

The Hacienda la Concepción subdivision is located in the vicinity of the La Concepción dam, in Santiago Cuautlalpan, State of Mexico, with a latitude of 19.685°, longitude of -99.286° and altitude of 2,340 m above sea level.

Solar radiation data were obtained from the weatherspark.com page, where statistical analysis of historical hourly climatological reports and model reconstructions from January 1, 1980 to December 31, 2016 of the four stations near Santiago Cuautlalpan is performed.

The statistical data mention that from March 9 to June 6 has the season with the highest solar radiation presenting average values greater than 6.9 kWh/m^2, being April the month that receives the highest radiation with average values of 7.3 kWh/m^2. From November 8 to January 25 is the period with the lowest direct radiation with average values of less than 5.4 kWh/m^2, with December having the lowest average value of 5.0 kWh/m^2. Table 1 shows the average values of solar radiation and cloud cover.

	Jan	Feb	Mar	Apr	may	jun	jul	aug	sep	oct	nov	dec
Solar energy kWh	5.3	6.2	7.0	7.4	7.2	6.5	6.3	6.2	5.8	5.7	5.3	5.0
Cloudy %	40	34	35	40	49	75	84	85	87	72	49	44
Clear %	60	66	65	60	51	25	16	15	13	28	51	56

Table 1 Monthly average incident radiation and cloudiness of Santiago Cuautlalpan
Source:https://es.weatherspark.com/y/5666/Clima-promedio-en-Santiago-Cuautlalpan-M%C3%A9xico-durante-todo-el-a%C3%B1o

Characteristics of the house

The property shown in Figure 1 has two levels and has a total area of 317.836 m^2.

Figure 1 Facade of the house
Source: Own elaboration

Table 2 shows a list of the equipment that consumes electrical energy at the site, giving a total of 3005 W of total installed load.

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First floor	Power W	Quantity	Subtotal W
40 inch TV	90	1	90
Blu-ray	34	1	34
Stove	635	1	635
Refrigerator	400	1	400
Washing machine	800	1	800
Light bulbs	25	12	300
		Total	**2259**
First level	**Power W**	**Quantity**	**Subtotal W**
40-inch TV	90	4	360
Blu-ray	34	4	136
Spotlights	25	10	250
Lap top		3	0
		Total	**746**
		Total	**3005**

Table 2 Equipment installed in the house
Source: Own elaboration

In order to know the annual consumption (KWh) of the house, the electricity bills provided by CFE on a bimonthly basis were considered. Table 3 shows the data provided by the electricity bills for the years 2021, 2022 and 2023 of the house.

Period	KWH	$	KWH ANUAL
03 FEB 23 to 04 APR 23	326	$ 569.00	
06 DEC 22 to 03 FEB 23	295	$ 431.00	
05 OCT 22 to 06 DEC 22	368	$ 732.00	
03 AUG 22 to 05 OCT 22	399	$ 851.00	
03 JUN 22 to 03 AUG 22	354	$ 657.00	
05 APR 22 to 03 JUN 22	340	$ 593.00	2198
02 FEB 22 to 05 APR 22	358	$ 658.00	
02 DEC 21 to 02 FEB 22	379	$ 734.00	
06 OCT 21 to 02 DEC 21	347	$ 601.00	
02 AUG 21 to 06 OCT 21	435	$ 822.00	
02 JUN 21 to 02 AUG 21	361	$ 598.00	2449
05 APR 21 to 02 JUN 21	377	$ 708.00	
02 FEB 21 to 05 APR 21	438	$ 938.00	
01 DEC 20 to 02 FEB 21	491	$1,136.00	
AVERAGE	**376**	**$ 716.29**	**2323.5**

Table 3 Bimonthly consumption taken from CFE bills
Source: Own elaboration

Since the pandemic forced people to stay in their homes, this increased electricity consumption for the year 2021, in order to have an estimate without pandemic, for the study we will consider the consumption of the year 2022, which was 2198 kWh, equivalent to 6022 Wh per day.

Methodology

For the sizing of the photovoltaic system, we will perform the following:

Determination of the number of photovoltaic panels

Determination of the number of batteries to be used

Angle of inclination of the panels.

Dimensioning of the photovoltaic system.

To determine the number of photovoltaic panels we will use equation 1:

$$Np = \frac{Average\ daily\ consumption\ Wh\ x\ Safety\ factor}{Panel\ power\ in\ W\ x\ Peak\ sun\ hours\ h} \quad [1]$$

The average daily consumption is 6022 Wh, for the safety factor, in the literature it is recommended to use values between 1.25 to 1.3, so for the study we will use 1.3.

For the power of the photovoltaic panel, there is already a great variety of photovoltaic panels on the market, which can be monocrystalline or polycrystalline. From a search, the Greenlux brand monocrystalline panel with a power of 540 W and a current of 9.67 A was selected.

The hours of peak sunshine are the number of hours in which we have a hypothetical constant solar irradiance of 1000 W/m2 on the photovoltaic panel. According to data from the Geographic Information System for Renewable Energies in Mexico (SIGER IIE-GENC) and the Solar Radiation Observatory of the Institute of Geophysics of the UNAM, the peak sunshine hours for a surface inclined to the latitude of the State of Mexico is 6.09 h. Therefore,

$$Np = \frac{6022\ Wh\ x\ 1.3}{540\ W\ x\ 6.09\ h} = 2.38$$

That is, 3 photovoltaic panels of 540 W of power are required.

When designing a photovoltaic system, it is necessary to consider backup batteries for the use of energy when there is no solar radiation, for example at night. To determine the capacity of the batteries, equation 2 is considered:

$$Cb = \frac{Average\ daily\ consumption\ x\ Days\ of\ autonomy\ D}{Depth\ of\ discharge\ x\ Battery\ voltage\ V} \quad [2]$$

The autonomy of the system considers the time we want to use the capacity of the battery when there is no light supply, for the study was considered half a day.

Also, from a search in the market, the battery that was selected for the system was the NM gel 12V - 230Ah, with a depth of discharge of 0.6. Therefore, the battery capacity will be:

$Cb = \frac{6022\ Wh\ x\ 0.5\ D}{0.6\ x\ 12\ V} = 418.9\ Ah$

The number of NM gel batteries to occupy is calculated with equation 3:

$$N_B = \frac{Required\ capacity\ Ah}{Battery\ capacity\ Ah} = \frac{418.9\ Ah}{230\ Ah} = 1.82 \quad [3]$$

That is, 2 batteries of 230 Ah are required to cover the demand for half a day.

For the installation of the system, the tilt angle of the PV panel is calculated with equation 4:

$$Inclination = 3.7 + (0.69xlatitude) \quad [4]$$

Therefore:

$Inclination = 3.7 + (0.69x19.685) = 17.28°$

For the location of the house with 19.685° latitude, the inclination of the photovoltaic panel should be 17.28°.

The Huawei top 5 world top 5 inverter 6.0KWP was selected for the system.

Table 4 shows the approximate costs of the selected equipment.

	Cost	Quantity	Subtotal
Solar panel	$ 12,000.00	3	$ 36,000.00
Battery	$ 9,000.00	2	$ 18,000.00
Inverter	$ 40,200.00	1	$ 40,200.00
		Total	$ 94,200.00

Table 4. System costs
Source: Own.

Conclusions

The use of renewable energies to reduce the consumption of fossil fuels is a good alternative, although the investment cost could be high, in the long run this cost can be reduced with what is no longer paid every two months for the cost of energy, in addition, with the support of the CFE modality of Home Interconnection Contract, the energy generated during the day and not used can be sold, for example, when everyone goes out to do their daily activities, increasing the recovery of the investment.

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References

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