Article **Journal-Macroeconomics and Monetary Economy**
June, 2021 Vol.5 No.8 23-30

Comparative analysis of performance, cost and energy production between the isolated and interconnected system of the corrugated cardboard company Puebla S.A. de C.V.

Análisis comparativo de rendimiento, costo y producción energética entre el sistema aislado e interconectado de la empresa cartón corrugado Puebla S.A. de C.V.

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DOI: 10.35429/JMME.2021.8.5.23.30 Received January 25, 2021; Accepted June 30, 2021

Abstract

Mexico aims to reduce emissions of greenhouse gases by 30% in the period 2020-2030, in order to achieve it have developed alternative technologies such as solar photovoltaic. In this type of technology come Corrugated Puebla SA The photovoltaic systems, so that in this work an autonomous photovoltaic sizing analysis was performed and interconnected network for company offices de CV in order to reduce the cost billing by Federal Electricity Commission. an energy analysis was performed and both photovoltaic systems were sized for the number of panels, inverters, wire gauges and structures were designed to install the system, the energy consumed by the company is 13.23 kWh / day. In the interconnected grid system investment it is 42.69% lower compared to the autonomous. The return on investment for the grid is 9 years and for self is 14 years.

Photovoltaic effect, Autonomous system network interconnected system, Panels, Regulators, Investors

Resumen

México tiene como objetivo reducir las emisiones de gases de efecto invernadero en un 30% en el periodo 2020-2030, para lograrlo se han desarrollado tecnologías alternativas como la solar fotovoltaica. En este tipo de tecnología entran los sistemas fotovoltaicos de Corrugados Puebla S.A., por lo que en este trabajo se realizó un análisis de dimensionamiento fotovoltaico autónomo y de red interconectada para las oficinas de la empresa de CV con el fin de reducir el costo de facturación por parte de la Comisión Federal de Electricidad. se realizó un análisis energético y se dimensionaron ambos sistemas fotovoltaicos por el número de paneles, inversores, calibres de cables y se diseñaron las estructuras para instalar el sistema, la energía consumida por la empresa es de 13.23 kWh/día. En el sistema de red interconectada la inversión es un 42,69% menor en comparación con la autónoma. El retorno de la inversión para la red es de 9 años y para la autónoma es de 14 años.

Efecto fotovoltaico, Sistema autónomo Sistema interconectado de red, Paneles, Reguladores, Inversores

Citation: FLORES, Oscar, GONZALES, Ricardo, JUAREZ, Victoria and HUITZIL, Ignacio. Comparative analysis of performance, cost and energy production between the isolated and interconnected system of the corrugated cardboard company Puebla S.A. de C.V. Journal-Macroeconomics and monetary economy. 2021. 5-8:23-30.

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Introduction

The main problem that exists worldwide is the excessive use of fossil fuels for the generation of electrical energy, which is necessary for all the activities of humanity, this causes irreversible climatic damage to the planet, a way to reduce this problem is the use of renewable energy such as solar energy, through the design, installation and commissioning of photovoltaic systems.

Mexico has a variety of resources to take advantage of, one of them is solar energy, since due to its geographical location the variety of climates and ecosystems allows the use of this resource, in particular the state of Puebla receives considerably good solar radiation. The conversion of solar energy to electrical energy is carried out by means of photovoltaic cells thanks to the photoelectric effect, this effect is based on the ability of some materials, in this case Silicon, to emit electrons when they are irradiated with certain frequencies of light. ultraviolet or visible.

In the present work, electrical and electronic materials were used to implement two photovoltaic systems; one island type and another with connection to the federal electricity commission network to supply the electrical needs of the company Cartón Corrugado Puebla SA de CV, located at Calle República del Perú 6A, residential Santa Cruz 72150 Puebla, Pue. Mexico.

It was found that the electrical needs of the company Cartón Corrugado Puebla SA de CV can be mitigated through these photovoltaic systems and it was noted that the system interconnected to the Comision Fedreal de Electricidad (CFE) network is cheaper than the autonomous system by 42.69 % , the only disadvantage of this system is that when there are power supply failures to the company by CFE, the photovoltaic system will not be able to remedy this lack of electricity because the investors cut off the supply for protection, instead with the photovoltaic system Autonomous if there will be electricity, since there will be a battery bank where the energy produced by the system that supplies the company is stored.

Background

Photovoltaic solar energy has been an elementary resource for the development of life on the planet, today it is an outstanding resource in the production of electrical energy, reaching a remarkable relevance throughout the world. In Mexico, the Federal Electricity Commission (CFE) has been producing electricity from solar energy in Sonora since 2008. A park was built to create electricity in Puerto Libertad, where 25 MW are produced.

In March 2007, the Mexican federal government authorized the injection into the electricity grid of small-scale solar energy production, that is, the surplus energy from small photovoltaic installations.

With this measure, it is intended that CFE take advantage of the energy surpluses of the electricity generating facilities through renewable procedures. With this regulation, photovoltaic installations will be allowed to sell their surplus production to the grid during times of sunshine and take it from it at times when it is not available. The foregoing, depending on the rates that are applied in the purchase-sale relationship of that energy by the CFE.

According to the National Association of Solar Energy (ANES), until 2006, practically all photovoltaic systems installed in Mexico were in applications isolated from the electrical network (rural electrification projects, communications, signs, water pumping) and yet, as of 2007, there are records of applications connected to the electricity grid. This trend has been maintained in subsequent years in such a way that in 2010, of the 35 MWp installed in that year, around 94% were systems connected to the electricity grid. In 2014, the Aura Solar I plant was installed in La Paz, Baja California Sur, a plant with a capacity of 39 MWp.

Other representative installations of photovoltaic systems connected to the grid (FVCR) are: Pilot system in Hermosillo, Demonstration system in Monterrey, Energy Research Center of the National Autonomous University of Mexico (CIE) in Temixco, Morelos, Popular Autonomous University of Puebla with a 75 kWp installation and the Amozoc Polytechnic University with a 50 kWp installation.

Within the applications of autonomous photovoltaic systems, space applications, telecommunications, electrification of rural and isolated areas, public lighting, water pumping stand out. The applications of interconnected systems are photovoltaic plants and photovoltaic buildings, as well as companies. These systems are integrated into roofs, walls and facades.

Objetives

General objective

Dimension and carry out an economic and energy comparison analysis between an autonomous photovoltaic system and an interconnected network for the offices of the company Cartón Corrugado Puebla S.A. de C.V.

Specific objectives

- Carry out an energy diagnosis of all the equipment and lamps in the offices of the company Cartón Corrugado Puebla SA de CV

- Calculate the number of system elements (panels, regulators, batteries and inverters).

- Compare autonomous photovoltaic sizing with grid interconnected based on costs and benefits.

Hypothesis

If the proper sizing and analysis of the cost and energy production of the autonomous photovoltaic systems and interconnected to CFE is carried out, a decrease in energy consumption can be observed, this will achieve economic savings, and it can be confirmed that the interconnected system is more suitable for the company Cartón Corrugado Puebla S.A. de C.V.

Justification

As is well known, photovoltaic energy is a clean and viable energy option to be implemented in the supply of electrical energy both in the home and in industry. Therefore, it is intended to make an autonomous and interconnected photovoltaic dimensioning in the offices of the company Cartón Corrugado Puebla S.A. de C.V., and thus reduce the cost of billing or become independent.

Likewise, the use of renewable energies would be promoted since the use of fossil fuels is generating major climate changes on the planet, such as the greenhouse effect, acid precipitation and the thinning of the ozone layer. With the economic and energy analysis, the decision can be made as to which system is more viable.

Materials and methodology

Materials

The materials used are:

- Samlez SAM-2000 inverter (Input characteristics: System battery voltage 12 VDC, input voltage range 10.5 to 15.0 (+/- 0.5) VDC, input current in continuous power 90.5 to 93.5 A. Output: output Voltage Modified Sine Waveform, Output Voltage 115VAC, Output Frequency 60Hz +/- 5%, DC Output 2000W, Highest Efficiency Point 90%).

- Solar Phono Module 150 W Polycrystalline. (Characteristics: Typical application 12 VDC, size 1482(L) x 676 (W) x 35 (H) mm, rated power 150 W, rated current 8.24 A, rated voltage 18.2 V, short circuit current 8.65 A, short circuit voltage open 22.8V).

- Battery Surrete Solar-480 (Capacity 135 Ah, voltage 12 V).

- SIGOR 12V, 40 A charge regulator. (Nominal voltage 12/24 V, maximum input voltage 50/60 V, maximum input current 30, 40 A, maximum output current 30.40 A).

- Fronius inverter 3.0-1. (Nominal power 3680 W, voltage range 90-450 V, nominal current 16 A, maximum number of inputs in parallel 2).

- Solar Phono Module 250 W Polycrystalline (Nominal power 250 W, nominal current 8.3 A, nominal voltage 30.2 V, short circuit current 8.70 A, open circuit voltage 37.8 V).

- Bidirectional meter.

- Structures for panels (Vento4basic).

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- Fuses.

- Rifle holder.

- Connectors.

- Photovoltaic cable.

- Multimeter.

Methodology

Method description

To carry out this project, the following steps were followed:

- Firstly, a study of the area where the photovoltaic system was implemented was carried out, obtaining data such as incident radiation, latitude, climatic variations, etc.

- The energy demand was determinedof the company Cartón Corrugado Puebla SA de CV carrying out an energy diagnosis which consists of accounting for the equipment used, obtaining its electrical characteristics, the time of daily use in hours and subsequently the appropriate calculation is made to obtain the total power required for the proper functioning of the company's equipment.

- Subsequently, the number of panels necessary to supply either partially or totally the energy demand was calculated, also the number of panels that must be connected in series and in parallel, the type of structure to be used to mount the solar panels was determined and finally, the optimum inclination that these should have with respect to the latitude of the place.

- The inverter was dimensioned, that is, we must select the appropriate inverter for our demand. For this, we make use of the aforementioned expression, which expresses that the power that our inverter must have must be approximately equal to the power that we must supply in AC, that is, the consumption that we must satisfy.

- Subsequently, the ideal wiring for our installation was calculated, in which great attention must be paid, since when energy passes through our cables, there will always be losses that are due to the voltage drops that are in them, in addition, these must meet with the Low Voltage Electrotechnical Standards.

Results and Discussion

Results

Table 1 shows the data forincident radiation, latitude, climatic variations, etc.; of the area in which the company is locatedPuebla Corrugated Cardboard.

Characteristic data of the area	
Coordinates	Latitude19°04′24″N Longitude 98°16′00″ W
Weather	Temperate Subhumid
Altitude	2,142 meters above sea level
average maximum temperature	28.5°
Average days with rain	110 days
Average number of cloudy days per year	80 days
Average number of sunny days per year	175 days
Peak solar hour hsol	5.5 h/day

Table 1 Characteristic data of the area

Table 2 shows the calculations of the energy consumed by the electrical and electronic devices of the company Cartón Corrugado Puebla.

Appliances	No. of devices	Power (W)	h/day	Wh/day
office spotlights	fifteen	25	9.5	3,562.5
hallway spotlights	5	25	2.0	250
bathroom spotlights	5	25	1.0	125
Computers	6	110	9.5	6,270
Fan	one	600	4.0	2,400
Laptop	one	81.70	7.0	571.9
Printer	one	18	3.0	54
Total				13,233.4Wh/day

Table 2 Total power consumed in the company Carton Corrugado Puebla S.A. de C.V.

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In order to carry out the adequate photovoltaic dimensioning for the company, the daily load was calculated using the total power and the power of the system that was implemented, as can be seen in equation 1:

$$C_{diaria} = \frac{P_{TOTAL\ Wh-día}}{V_{sistema}} = \frac{\frac{13{,}233.4Wh}{día}}{12V} = \frac{1{,}102.78Ah}{dia}$$

In order to compensate for the losses in the batteries and other components we use equation 2:

$$l_s = C_{diaria} \times f_{seguridad} = 1{,}102.78Ah/dia \times 0.2 = 220.55Ah/dia$$

To calculate the corrected current daily load in amp hours per day, we apply Equation 3:

$$C_{dcc} = C_{diaria} \times f_{seguridad\ total} = \frac{1{,}102.78Ah}{dia} \times 1.2 = \frac{1{,}323.33Ah}{dia}, \ (3)$$

$donde\ f_{seguridad\ total} = 120\%$

The current AS that the system will have to produce is obtained with the following equation 4.

$$A_S = .\frac{C_{dcc}}{h_{sol}} = \frac{1{,}323.33Ah/dia}{5.5\ h/día} = 240.60A(4)$$

To obtain the number of modules we use the current ASm produced by the proposed module for the system, and the amperage that the system will have to produce, as shown in equation 5:

$$N_m = .\ (5)\frac{A_S}{A_{Sm}} = \frac{240.60A}{8.24A} = 29.19$$

Rounding up we have 30 modules.

To obtain the current produced by the modules, equation 6 is used:

$$C_{pm}, (A) = N_m \times A_{Sm} = 30x8.24\ A = 247.2\ A\mathrm{T}$$

The number of regulators Nr is calculated with the current Cpm produced by the proposed module and the current Cr supported by the regulator, as shown in equation 7:

$$N_r = \frac{C_{pm}}{C_r} = \frac{247.2A}{40A} = 6.18$$

Rounding up we have 7 sliders.

The nominal capacity of the Cnb batteries is calculated knowing the days of autonomy, which in this case was chosen as 5 and the depth of discharge Dp = 80%, as shown below 8:

$$C_{nb} = \frac{C_{dcc} \times d_a}{D_p} = \frac{(1{,}323.33Ah/dia)(5dias)}{0.8} = 8270.81Ah$$

To obtain the number of batteries, the nominal charge of the Cnb batteries and the nominal charge of a Cn battery are used, for this system it is 135Ah, as shown in equation 9.

$$N_b = \frac{C_{nb}}{C_n} = \frac{8270.81Ah}{135Ah} = 61.26$$

Rounded up we have batteries 62 batteries.

Knowing the output power Ps of the inverter, which is 2000 W, and knowing the performance factor η = 90%, we can obtain the input power Pe, using equation 10.

$$p_e = \frac{p_s}{\eta} = \frac{2000w}{0.90} = 2{,}222.22w$$

Then the total power is divided by the input power to obtain the number of inverters:

$$\frac{13{,}233.4w}{2{,}222.22\ \mathrm{w}} = 5.95$$

Rounding up, there are 6 inverters for the autonomous system.

To calculate the gauge of the cable to be used in the different sections of the system, the following equation was used:

$$S = \frac{2LI}{\sigma(v_a - v_b)}$$

Where:

S = section in mm^2

L= Length in meters to the receiver

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I= current in amps

$(v_a - v_b)$=voltage drop in volts

σ=conductivity (inverse of resistivity, copper=56)

The total copper cable used for the stand-alone system was 84 m of 6 AWG gauge and 100.32 m of 8 AWG gauge.

Figure 1 shows the arrangement of the autonomous photovoltaic system made based on the calculations obtained previously, where the modules, regulators, batteries, inverters and consumption in direct current and alternating current are observed.

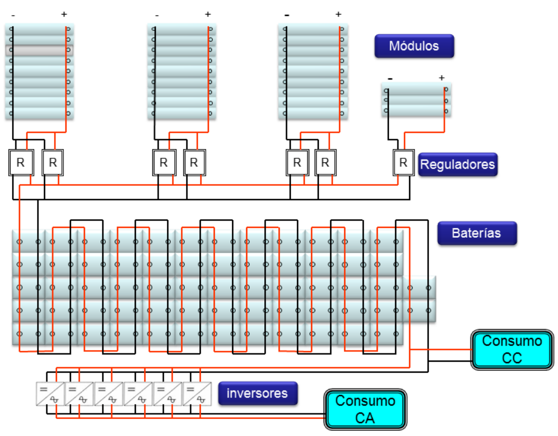

Figure 1 Autonomous photovoltaic system

Calculations made for a photovoltaic system interconnected to the grid

With the energy diagnosis, the total power of the system was obtained, which was 13,233.4 Wh/day, and with the value of the power of the inverter so that it works properly we can obtain the number of inverters, this was done using equation 12:

$$n_{inversores} = \frac{p_{total\ wh-dia}}{p_{inversor}} = \frac{13{,}233.4wh/dia}{3{,}450w} = 3.83$$

With this value, it was decided to use 4 inverters.

The arrangement of the photovoltaic panels is determined based on the input specifications of the inverter, and the output specifications of the photovoltaic panel, therefore we have:

$$No.\,de\ modulos\ en\ serie = \frac{V_{inv}}{V_M} = \frac{210V}{30.2V} = 6.34$$

Rounding up we have 7 modules in series.

To obtain the number of modules in parallel we use the inverter input current Iinv and the module current IM, as shown in equation 13:

$$No.\,de\ modulos\ en\ paralelo = \frac{I_{inv}}{I_M} = \frac{15\ A}{8.3A} = 1.8$$

Rounding up we have 2 modules in parallel.

To calculate the number of modules we apply equation 14.

$$n_{modulos} = (No.\,de\ modulos\ en\ paralelo \times\ No.\,de\ modulos\ en\ serie \times n_{inversores}) == (2\ modulo\ en\ paralelo\ \times 7modulos\ en\ serie\ \times 4\ inversores) = 56\ modulos$$

The minimum distance between panel edges to avoid shadowing another panel was 1.74 m.

Total cable used for a system connected to the network is 100m of 8 AWG gauge and 24m of 4 AWG, this was obtained with equation (11).

Figure 2 shows the photovoltaic system interconnected to the grid, elaborated with the data obtained from the previous calculations where the different components that make up a system interconnected to the grid are observed.

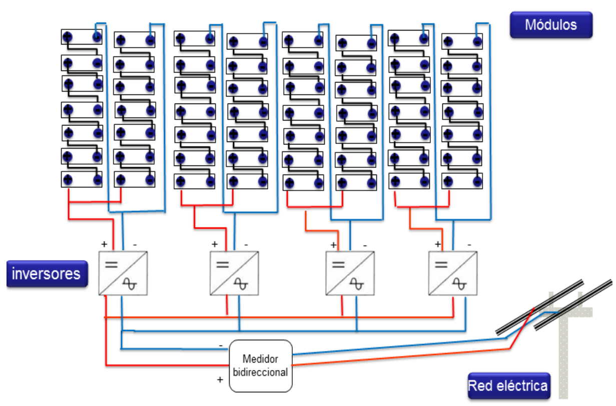

Figure 2 Photovoltaic system interconnected to the network

Tables 3 and 4 show the price of a photovoltaic system interconnected to the network and an autonomous one, where the prices per unit of each element and the total price of each of the systems can be seen.

Product	No. of products	$ Unit price	$total price
150w polycrystalline solar phono module	30	3200	96,000
Surrete solar battery s-480	62	4000	248,000
Zygor regulator	7	3995	27,965
samlex sam-1000 inverter	6	4500	27,000
6AWG wire	100.32 m	32.5 m	3,607.5
8AWG wire	84 m	28 m	2352
Vento4basic (capacity of 4 panels)	7	850	5,950
Vento2adic (capacity of 2 panels)	1	500	500
Protective elements.	Various	4000	4000
Total price for all system components: $413,374.50			

Table 3 Costs of the elements of an autonomous photovoltaic system

Product	No. of products	$unit price	$total price
Solar phono module 250w polycrystal linen	56	3,500	196,000
xantrex GT5 inverter.	4	6,000	24,000
6AWG wire	24 m	32.5 m	780
8AWG wire	100 m	28 m	2800
Vento4basic (capacity of 4 panels)	14	850	11,900
Protection and installation elements.	various	10,000	10,000
Total price for all system components $235,840.00			

Table 4 Costs of the elements of a network interconnected system

Discussion

According to the results, we can say that the interconnected photovoltaic system is more energy efficient since we will always have electrical energy despite if the days do not have enough radiation, since the current that is needed for the equipment to function will be taken from the grid CFE.

On the other hand, an autonomous system would not have the capacity to fill the batteries 100% and would not be able to power all the company's equipment and when there is enough radiation, it can be wasted since once the batteries are full, the charge regulator cuts off the passage of the current to prevent them from being damaged, instead the interconnected system injects the excess energy into the CFE network so that in the end the company reduces the cost of the energy used.

The interconnected system is also more efficient in terms of space, since the 62 batteries occupy a larger area than the bidirectional meter and care for the batteries must be special since they can be damaged by moisture.

The interconnected photovoltaic system is less expensive than the autonomous system as seen in the prices; in 42.6% this makes the interconnected network more attractive since the return on investment is faster. Autonomous systems could be made more efficient but these would become even more expensive, due to the increase in the number of batteries and the fact that only 80% of the energy stored in them can be extracted

Gratitude

The researchers thank the Polytechnic University of Amozoc and the company Cartón Corrugado Puebla SA de CV for the support provided for the development of this project.

Conclusion

Based on the data obtained, it was concluded that both systems supply the consumption of electrical energy within the company Cartón Corrugado Puebla SA de CV However, in the system interconnected to the network, the investment is 42.69% lower compared to the autonomous system, the advantage The main thing about autonomous is that it is not dependent on the network.

Finally, it can be said that the system interconnected to the CFE network is more viable for the company Cartón Corrugado de Puebla SA de CV, since it is more efficient and less expensive.

In addition, its return on investment is approximately 9 years, while the autonomous system, its return is 14 years, but this period can be increased since at 5 years or earlier the batteries would have to be changed and therefore the cost of the system. autonomous would increase.

For the interconnected photovoltaic system, maintenance is almost zero and the system has a useful life of approximately 25 years, while the autonomous system requires more maintenance, especially in the batteries, since their life cycle is approximately 5 years. With this system, 8.6 tons of carbon dioxide are not emitted into the atmosphere per year, helping to reduce climate change.

References

Sanchez M.A. (2014). Photovoltaic Solar Energy. Mexico. 314 p.

Jutglar L. (2012) Photovoltaic solar power generation. Spain. 210 p.

Flores O. Reduction of the energy efficiency of the photovoltaic system of the Aura Solar I plant. (2015). Mexico. 850- 855 p.

flowers oGreen clinic with solar tracker. (2014). Mexico. 20 – 32 pg.

Guerrero C. (2010). Design Proposal for a Photovoltaic System Interconnected to the Grid for a Residential House in Xalapa. Recovered from:

http://cdigital.uv.mx/bitstream/123456789/32879/1/guerrerogutierrez.pdf

Anguiano J. (2012). Solar constant. Pag.15 - 17 Impact of the temperature of the modules on the efficiency of a photovoltaic system connected to the network. Retrieved from: http://148.206.53.84/tesiuami/UAMI16030.pdf

Anguiano J. (2012). Types of photovoltaic cells p. 55, Impact of Module Temperature on the Efficiency of a Photovoltaic System Connected to the Grid. Retrieved from:http://148.206.53.84/tesiuami/UAMI16030.pdf

White I. (2008). Photovoltaic Solar Installation Connected to the Grid on the Roof of an Industrial Warehouse. Recovered fromhttp://e-archivo.uc3m.es/bitstream/handle/10016/6063/PFC_Israel_Blanco_Sardinero.pdf?sequence=1

Prado C. (2008). Design of a Photovoltaic Electrical System for an Isolated Community. Recovered from: http://eie.ucr.ac.cr/uploads/file/proybach/pb0831t.pdf.