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Comprehensive Proposal For Photovoltaic Systems For Schools And Public Markets In Mexico City

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Abstract:
Background*: It is well known that solar energy, as a renewable and inexhaustible energy source, is always available and can be transformed and stored as electrical energy. Mexico City and its metropolitan area are located in a region with intense solar radiation, comparable to that of countries like China, Singapore, Australia, and India. Faced with the crisis of non-renewable energy sources and environmental pollution, the use of photovoltaic systems emerges as a viable alternative to mitigate the negative impact on the environment. These systems, with a great development and technological advance, allow the generation of electrical energy from solar cells that convert sunlight into electricity through simple mechanisms. Despite its potential, Mexico City does not take advantage of solar energy as other countries with similar conditions do. The production of electrical energy from this resource is minimal. It is important to demonstrate the potential of solar energy in Mexico City. Implementing these technologies in the generation of electrical energy for schools and public markets in the city and the metropolitan area would make them sustainable and contribute to the fight against climate change.*
Materials and Methods*: In this research, a software is used and it is studied that Mexico City has a large educational system with 156,385 public schools that consume 4805 GWh/year and 329 public markets that consume 3868 KWh/year[1],[2].*
To determine the size of a photovoltaic system for these installations, commercial software is used that is efficient and economical. This software stands out for being free in its demo version and for being effective for sizing large systems.
Results*: The software will finally provide a complete estimate of the different components and brands thereof, allowing an optimal implementation of the photovoltaic system. Although there are various software tools for sizing these systems, the one used in this study stands out for its versatility and effectiveness. Additionally, the $2,410.79 annual license is relatively inexpensive and pays back quickly, making it an attractive option for large-scale project development.*
Conclusion: *Taking advantage of the photovoltaic potential in Mexico City is a viable and beneficial alternative for the environment, public health and the economy. The use of software tools facilitates the design and optimization of large-scale photovoltaic projects, such as those that could be implemented in schools and public markets in the city.*
Key Word*: energy, photovoltaic solar panel, renewable energies, radiation, photovoltaic cells.*

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I. Introduction

The supply of electrical energy in schools and public markets is essential for the development of daily activities, both for commerce and education. However, the traditional generation of electrical energy from non-renewable resources has a significant environmental impact, contributing to climate change and deteriorating the health of the population[3].

In this context, photovoltaic solar energy is presented as a viable, sustainable and low environmental impact alternative. This technology allows sunlight to be transformed into electrical energy in a clean and efficient way, without polluting emissions [4].
The main objective of this article is to demonstrate the potential of photovoltaic solar energy to cover the energy needs of schools and public markets in Mexico City. To do this, the technical and economic feasibility of implementing photovoltaic systems in these spaces will be analyzed, considering the urban context and the climatic characteristics of the city [5].

The study will focus on the following aspects:
1. Evaluation of the current energy consumption of public schools and public markets.
2. Analysis of the solar potential of Mexico City.
3. Sizing of photovoltaic systems through commercial software.
4. Economic and environmental evaluation of the implementation of photovoltaic systems.

It is expected that the results of this study will contribute to decision-making regarding public policies, promoting the adoption of solar photovoltaic energy in schools and public markets in Mexico City [6].
Below is a brief description of the benefits of solar photovoltaic energy:
Clean and renewable energy: It does not generate polluting emissions or waste, contributing to the protection of the environment.
1. **Sustainability:** It is based on an inexhaustible natural resource such as sunlight.
2. **Profitability:** Allows you to reduce energy costs in the long term.
3. **Energy independence:** Reduce dependence on fossil fuels and traditional electrical grids.
4. **Improved air quality:** Reduces air pollution and improves public health.

The implementation of photovoltaic systems in schools and public markets in Mexico City would not only provide environmental and economic benefits, but would also contribute to the creation of a more sustainable and resilient city to climate change [7].

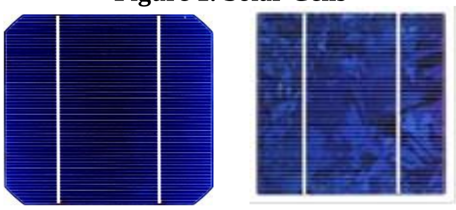
II. Material And Methods

These prospective Photovoltaic systems: Solar energy or solar radiation can be transformed into electrical energy, using semiconductor devices called solar cells, with different degrees of energy efficiency, whether monocrystalline or polycrystalline cells. Photovoltaic solar energy is a renewable energy source that produces renewable electricity obtained from solar radiation using a semiconductor device called a photovoltaic cell or cell. Photovoltaic cells that are manufactured with semiconductor materials are the basic component of a photovoltaic system. A certain number of solar cells appropriately interconnected with each other form a photovoltaic module or panel. Multiple modules can be connected to form an array, in turn, these arrays can be connected together in parallel or series to obtain more current or more power as required [8].

In recent years, photovoltaic systems have become a form of effective electrical energy production, especially in places with good solar intensity or radiation, thanks to their relatively simple installation and the costs of the different components of photovoltaic systems. They have been reduced little by little and in addition the subsequent maintenance of the equipment has also been reduced [9].

Components of photovoltaic systems: Solar cell. Semiconductor element that has the ability to convert solar radiation directly into electrical energy. This is due to the photovoltaic effect, figure 1.

Figure 1. Solar Cells



Photovoltaic modules or panels: Devices that convert sunlight into electricity. These are made up of a set of photovoltaic cells interconnected in an orderly manner, forming a panel. The main function of this panel is to generate voltage and direct current at a certain value, measured in watts.

Photovoltaic cells are the fundamental component of solar modules. Made from semiconductor materials, these cells generate an electrical current when exposed to sunlight. The amount of electricity generated depends on various factors, such as the efficiency of the cell, the amount of sunlight it receives, and its area. Figure 2.[8]

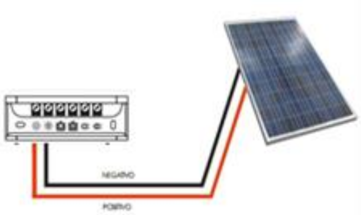
Figure 2. Photovoltaic panels

Photovoltaic System: Set of photovoltaic modules or panels arranged and interconnected in such a way that they produce electrical energy in direct current, according to a specific design. The power in watts may vary, due to its manufacture and size, figure 3.

Figure 3 Photovoltaic systems.

Charge regulator: Electronic device, responsible for regulating the voltage delivered by the photovoltaic system to the inverter. Generally this device is used for isolated systems, that is, systems that have deep charge storage batteries, figure 4.

Figure 4. Regulatory device.



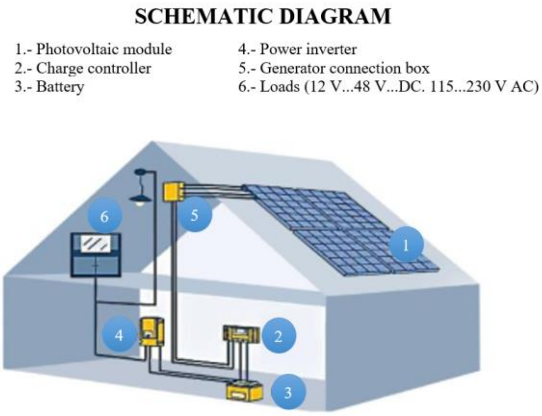
Inverter: Electronic device, whose main function is to convert the electrical energy delivered by the photovoltaic system, from direct current (DC) to alternating current (AC), figure 5.

Figure 5. Inverter

Basic Ways Of Supplying Electrical Energy Generated By Photovoltaic Systems.
Isolated Systems (Not Interconnected To The Electrical Grid).

An isolated photovoltaic system or not interconnected to the grid, is a system that does not interact with the electrical energy of the CFE (federal electricity commission, Mexico), and makes use of electrical energy storage systems in deep charge batteries, figure 6. [7]

Figure 6. Isolated system

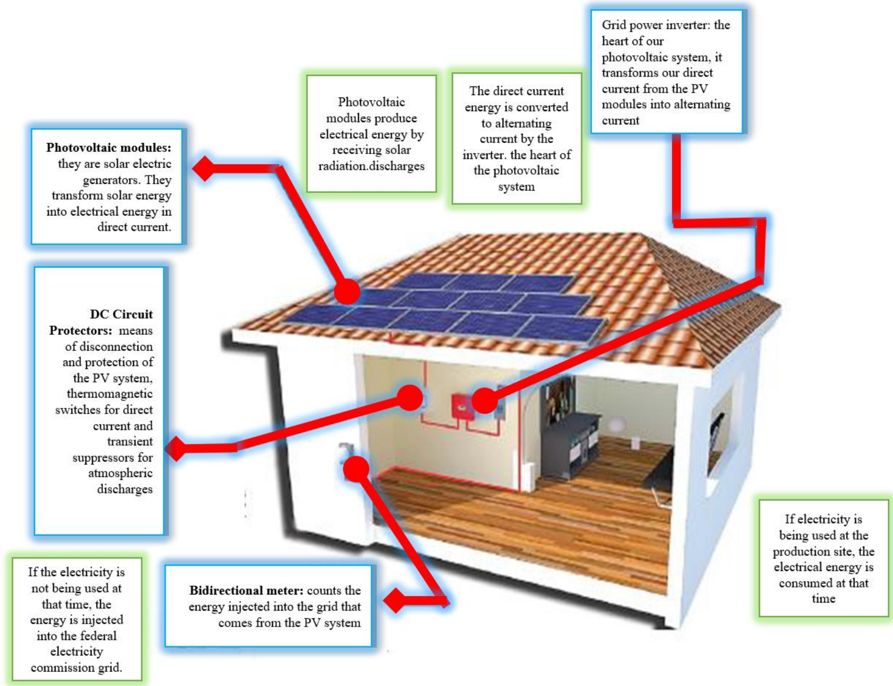


Systems Interconnected To The Electrical Grid (Cfe).

A system interconnected to the electrical grid is one that supplies electrical energy to the environment and what is not used is sent to the electrical grid, that is, the end user uses the electricity generated for consumption and only the surplus is fed to the electrical grid. network (CFE) figure 7.

The fundamental objective is to generate the greatest amount of electrical energy through the solar panels during the day, taking advantage of the intense solar radiation, placing the panels or solar panel system in strategic places, preferably on the roof of the property, with the correct and optimal orientation and inclination. The generation of electrical energy from the panels is variable depending mainly on: model and manufacturing, capacity, size and geographical location. The panels or panel systems will be interconnected to a central inverter or micro inverters, which convert the Direct Current (DC) energy generated by the solar panels into Alternating Current (AC) energy. This electrical energy will be consumed by the property and the surpluses will be injected into the network. The bidirectional meter will be responsible for measuring both the energy consumed by the school or commercial building, and that which is returned to the public electricity grid (CFE).[6]

Figure 7. System interconnected to the network.



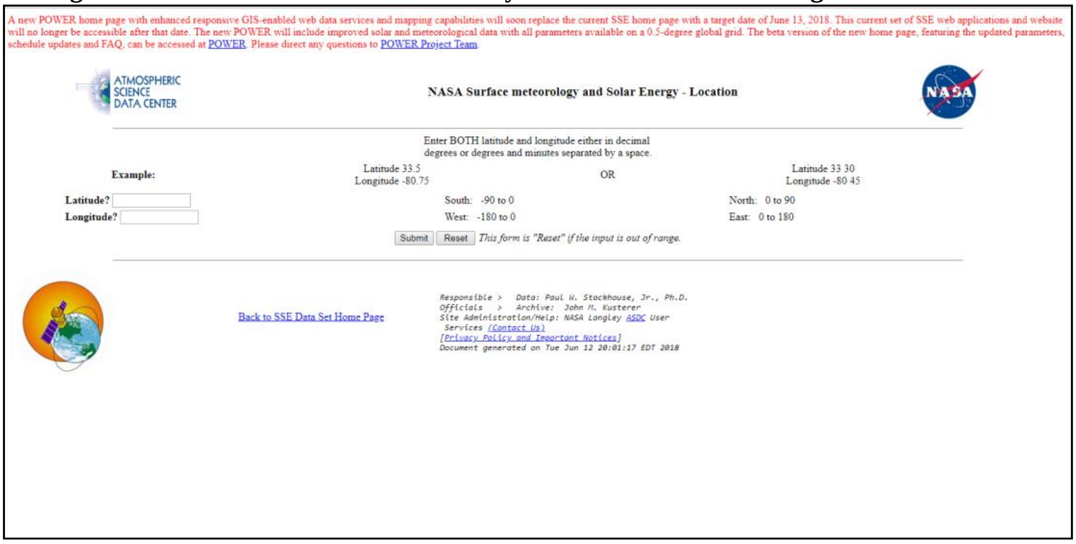
Calculation or Sizing of a photovoltaic system, which can be applied to schools or public markets in CDMX.

In Mexico City there are approximately 156,385 public schools, from primary to postgraduate levels, which consume approximately 4805 GWh/year, and 329 public markets, which consume approximately 3868 KWh/year. Although, to make a good calculation of the size and numbers of components that involve a certain system, there are various engineering techniques to calculate the quantity and characteristics of the devices to be used in a certain project, commercial software will be used that performs the calculations corresponding to a specific project. There are many software tools that perform these sizing, however, the one used for this article is a free and relatively inexpensive demo and very effective for sizing a system, no matter how large it may be.

Starting with the calculation of the power or daily consumption of the place, in this case it is a public market or a school in CDMX, whose coordinates are: Latitude: 190 25' 42' N, Longitude 990 07' 39" W and that They will be very useful for correct sizing of the photovoltaic system. This tool is available on the web and is provided by NASA, figure 8.

Taking into account the data generated based on the coordinates entered, from table 1, to achieve consumption in Kwh/day, an average of consumption in the last year must be made, to conclude by dividing by 365, which are the days which contains the year. Calculation carried out automatically by the software used.

Figure 8 Tool to determine solar intensity based on latitude and longitude coordinates.



This NASA tool will provide us with values and variables to supply to the software and make an estimate of the system components, depending on the size of the school or market, in which the design of the photovoltaic system will be made.

Table 1 Table of solar radiation according to the coordinates of the geographical area of interest.

Homepage (Units & Definition)

ATMOSPHERIC SCIENCE DATA CENTER

NASA Surface meteorology and Solar Energy: RETScreen Data

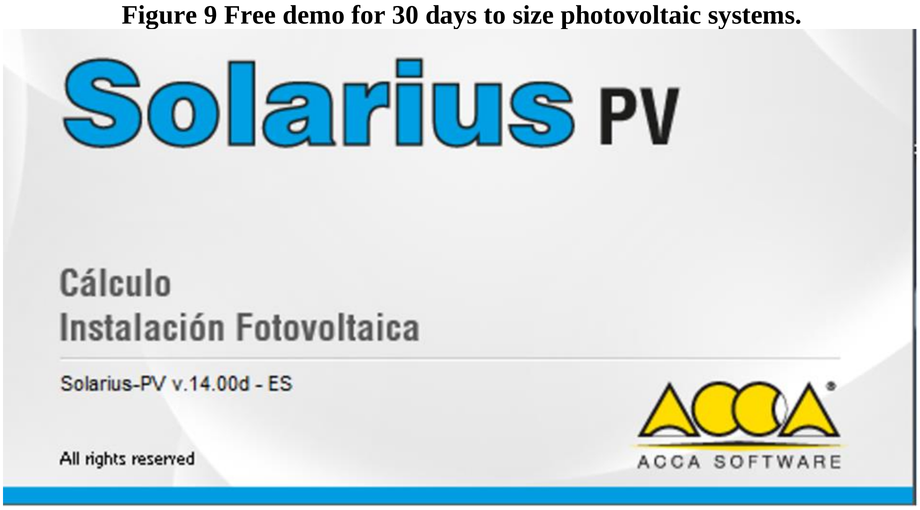
Latitude 19.429 / Longitude -99.181 was chosen.

	Unit	Climate data location
Latitude	°N	19.429
Longitude	°E	-99.181
Elevation	m	1928
Heating design temperature	°C	6.57
Cooling design temperature	°C	25.48
Earth temperature amplitude	°C	16.74
Frost days at site	day	0

Month	Air temperature	Relative humidity	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days	Cooling degree-days
	°C	%	$kWh/m^2/d$	kPa	m/s	°C	°C-d	°C-d
January	12.8	59.7%	4.78	81.2	3.1	14.9	149	100
February	14.4	53.2%	5.73	81.1	3.2	17.4	95	131
March	16.7	45.7%	6.55	81.0	3.5	20.8	47	209
April	18.9	46.9%	6.50	81.0	3.4	23.5	13	263
May	19.5	55.2%	6.24	81.0	3.1	23.6	5	297
June	18.6	70.3%	5.60	81.0	2.9	21.0	4	264
July	18.0	69.0%	5.51	81.2	2.8	20.2	9	255
August	18.1	68.6%	5.42	81.1	2.6	20.2	5	259
September	17.3	74.1%	4.95	81.0	2.4	19.1	19	229
October	15.9	72.0%	4.92	81.1	2.6	17.7	55	194
November	14.4	67.6%	4.81	81.2	2.9	16.1	94	145
December	13.0	64.0%	4.49	81.2	2.9	14.7	139	110
Annual	16.5	62.2%	5.46	81.1	3.0	19.1	634	2456

The sizing for the photovoltaic system, as mentioned above, can use the already known engineering equations and formulas, to perform the calculations and obtain the parameters of the components that can be used, however, this economical software that does more quickly and effectively, the correct sizing of the different components that will be used in the system. It is enough to enter the coordinates of the area of interest, and once the relevant data is known, it will be supplied to the software, in this case it is the *Solarius_PV_v1400c_ES* software, figure 9. There are many software packages for this purpose, but This is one of the best, because it makes very precise calculations. Solarius PV is the software for sizing and calculating photovoltaic installations chosen by thousands of professionals around the world. It is quite versatile software and can calculate photovoltaic systems very accurately.

Figure 9 Free demo for 30 days to size photovoltaic systems.



The following figure 10 shows the graph of solar radiation at peak hours in the region of interest. For this case, coordinates of the Azcapotzalco delegation, in CDMX, were entered. The graphs obtained by the software are very similar to those provided by the UNAM Geophysics Institute, figure 11.

Figure 10. Solar radiation intensity during peak hours.

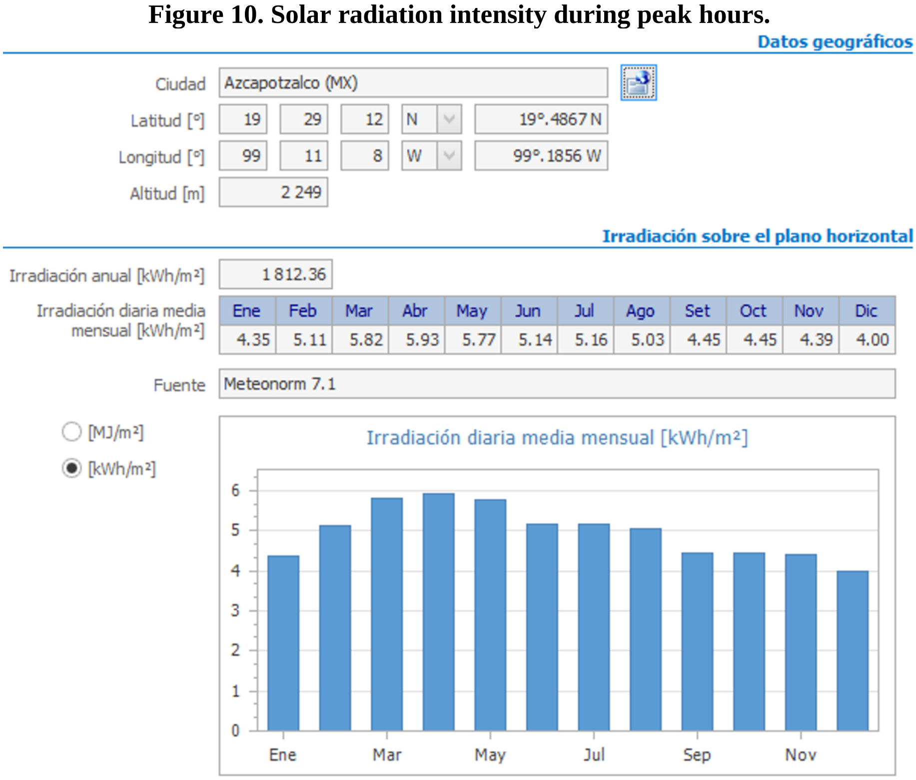
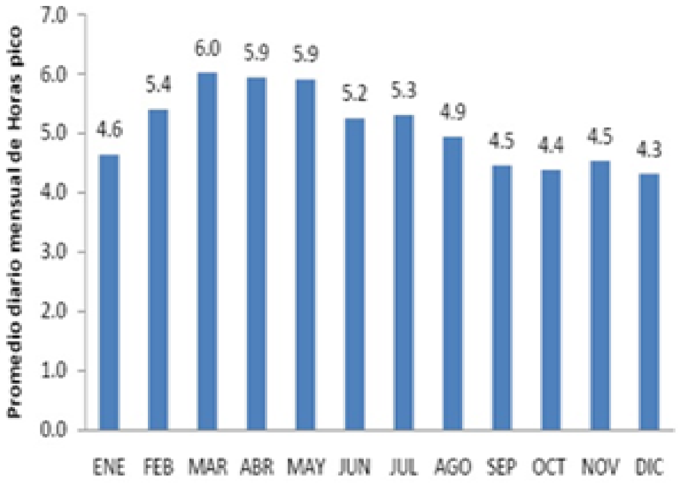


Figure 11 Solar radiation intensity during peak hours.



Subsequently, the tool will provide the characteristics and numbers of components to create the photovoltaic system, figure 12 and figure 13.

Figure 12 Photovoltaic system data 1

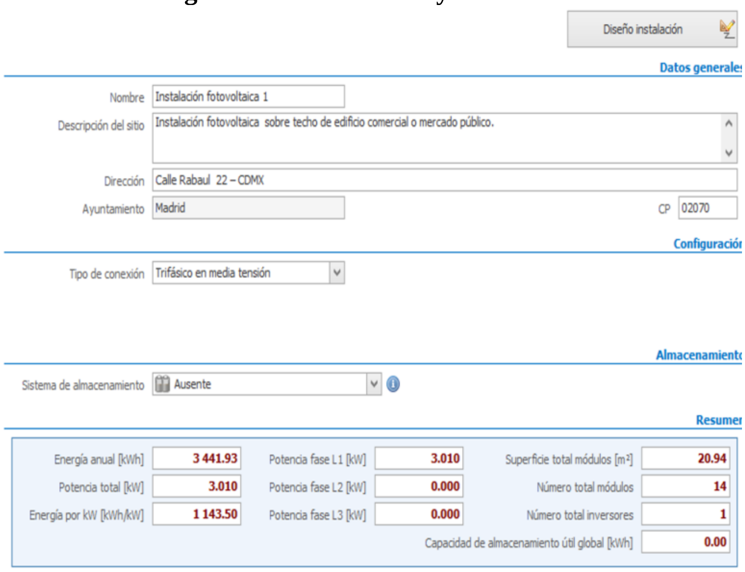
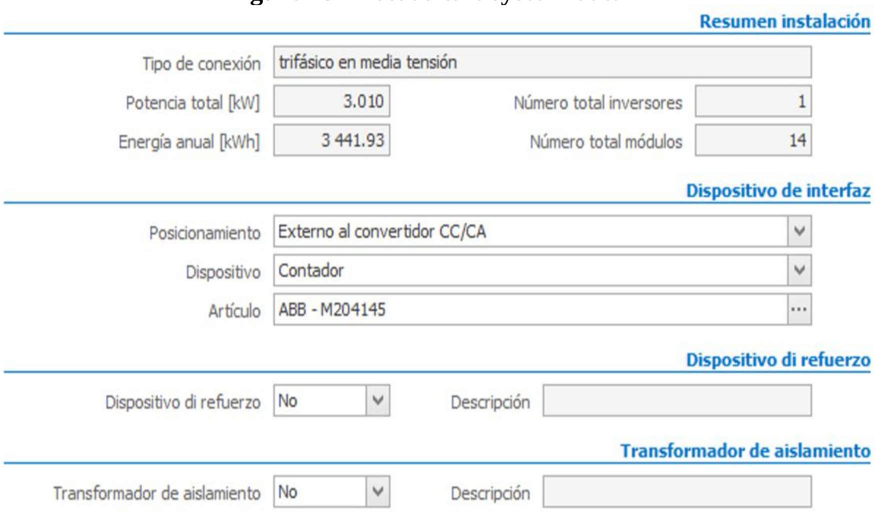


Figure 13 Photovoltaic system data 1



III. Result

The software provides a complete estimate of the different components and brands required for optimal PV system implementation.

There are various software tools for sizing photovoltaic systems. The choice of this particular software is due to its versatility and effectiveness, in addition to the affordable cost of the annual license, which amounts to $2410.79. This investment is quickly recovered thanks to the savings generated by the photovoltaic system.

The software allows:

- Carry out precise and personalized sizing.
- Select between different brands and models of components.
- Obtain a detailed estimate of investment costs.

In short, the software is a valuable tool for the planning and implementation of photovoltaic systems. Its use facilitates decision making and allows optimizing system performance.

IV. Conclusion

Mexico City has a high potential for the use of photovoltaic systems in the industrial, public and residential sectors. Its technical feasibility has been demonstrated, and its implementation would not only imply a reduction in the consumption of fossil fuels for electricity generation, but would also provide important environmental and public health benefits.

It is estimated that the photovoltaic potential in these three sectors amounts to 17,794 MW, which would translate into the avoidance of 291 Mt of CO_2 [1] emissions during the useful life of the systems.

The use of software tools for sizing photovoltaic systems represents a significant improvement over traditional calculation methods. These tools allow you to optimize the system design, reducing time and associated costs.

Among the various tools available, the one used in this study stands out for its ease of use, economy and effectiveness. This tool allows for large-scale and complex projects, such as the design of photovoltaic systems for schools and public markets in Mexico City.

In short, Mexico City presents a favorable scenario for the adoption of photovoltaic systems. Its implementation would provide economic, environmental and public health benefits, consolidating itself as a viable alternative for the generation of sustainable energy.

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