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Sizing of a Photovoltaic System in the City of Quevedo for Residential Use

Dimensionamiento de un Sistema Fotovoltaico en la Ciudad de Quevedo para Uso Residencial

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Abstract

The sizing of a small photovoltaic system of a residence in the city of Quevedo is presented, with the objective of analyzing solar photovoltaic installations as a measure to promote the use of distributed generation in homes and the reduction of costs to be paid for electricity consumption. The load profile of the residence is made through personal estimates and the global horizontal solar irradiation and temperature data are obtained from NASA's Surface meteorology and Solar Energy (SSE) weather database. They will then be entered into the HOMER Pro software for the respective simulations with different types of photovoltaic systems.

Keywords: sizing, photovoltaic system, generation, renewable, grid-connected.

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Resumen
Se presenta el dimensionamiento de un pequeño sistema fotovoltaico de una residencia en la ciudad de Quevedo, con el objetivo de analizar las instalaciones solares fotovoltaicas como una medida para fomentar el uso de la generación distribuida en los hogares y la reducción de los costos a pagar por el consumo eléctrico. El perfil de carga de la residencia es realizado a través de estimaciones personales y los datos de irradiación solar horizontal global y de temperatura se obtienen a partir de la base meteorológica Surface meteorology and Solar Energy (SSE) de la NASA. Posteriormente serán introducidos en el software HOMER Pro para las respectivas simulaciones con diferentes tipos de sistemas fotovoltaicos.

Palabras clave: dimensionamiento, sistema fotovoltaico, generación, renovables, conectado a red.

Introduction

The increase in the use of renewable energies has become remarkable due to the awareness of optimizing resources and reducing environmental pollution, this causes the need to generate new projects that contribute to the improvement of this type of systems Salamero et al. (2009) indicates that a photovoltaic generation system is proposed in which the advantages and disadvantages of an isolated system with respect to a system interconnected to the grid will be analyzed and compared. In addition, the economic analysis of both systems will be presented, which will allow deciding which of them is adequate for the sizing of the system for a residence. For Farfán et al. (2015) there are 3 types of PV systems that can be implemented:

Off-grid or isolated system

The greatest development of this energy source is undoubtedly in rural areas (electrification of houses, farms and hamlets) or in isolated locations where electricity supply is often impossible by other means. (Solar Energy Aragon)

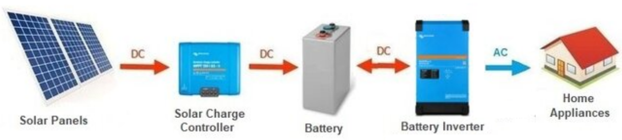

Figure 1. Basic diagram of an off-grid photovoltaic system.

On-grid or grid-connected system

A grid-connected photovoltaic system can be defined as a photovoltaic generation system that works in parallel with the utility grid, i.e., the outputs of both generation systems are connected to each other, so that the first one acts as if it were another generator of the utility, injecting electricity into its distribution network.

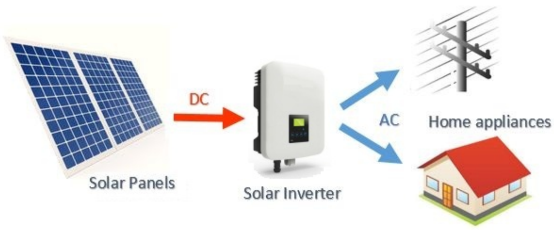

Figure 2. Diagram of on-grid photovoltaic system.

This is why for Cossoli et al. (2014) in general terms, grid-connected distributed PV generators can bring significant benefits to distribution systems, as well as from the location of these within the grid.

Hybrid, grid-connected system with batteries

In this case Cáceres et al., (2014) indicates that hybrid systems generate power in the same way as a common grid-connected system, but use special hybrid inverters and batteries to store energy for later use. This ability to store energy allows most hybrid systems to also function as a backup power source during a blackout, similar to a UPS system.

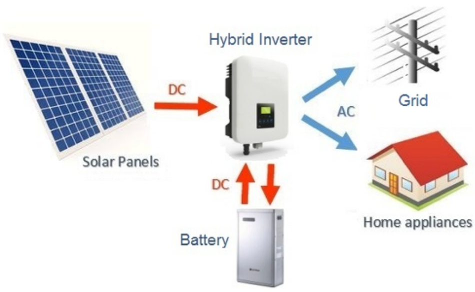

Figure 1. Hybrid photovoltaic system diagram

Traditionally, the term hybrid refers to two generation sources such as wind and solar, but in the solar world the term "hybrid" refers to a combination of energy storage and solar power that is also connected to the grid. (Farhat et al., 2015, p. 480)

Components of a photovoltaic system

Solar panels: convert solar radiation into direct current. The higher the radiation, the more energy the solar panels will produce at the same power.

Charge regulator: it acts by cutting and regulating the energy flow between the panels and the battery, depending on the battery's state of charge. In order for it to work properly, its power must be sized correctly and the right type must be chosen to obtain the best performance from the panels. Charge regulators can be of 2 types:

PWM regulators: it is more economical and recommended for small low-cost solar systems. It can only be used if the nominal voltage of the solar panels and batteries is the same, for example, with 12V solar panels and 12V batteries.

MPPT regulator: they are much more efficient as they adjust the incoming panel voltage to that required by the battery according to its charging stage, so they can extract about 30% more energy than a PWM. The only requirement is a nominal voltage in panels higher than the working voltage in batteries and they are the only possible option when using panels with a non-standard voltage. (Auto Solar, 2020)

Off-grid inverters: isolated inverters need to be connected to batteries and are responsible for converting the direct current that can be extracted from them to alternating current suitable for normal household consumption. Seraphim et al. (2014) states that generally, they can be of: 12V, 24V or 48V and it is important that they generate a pure sine wave so as not to have breakdowns in the electrical devices that are connected. It is common to integrate the charge regulator within the inverter itself and also the functionality of a battery charger from an external source. This is very useful because in isolated installations it is common to have a gasoline generator or diesel generators that can cover emergency consumption in low production conditions. p. 1482

Microinverters vs. central inverters: the great advantage of a microinverter over a central inverter is that the system is not affected by shadows. That is, if one panel is affected by a shadow the other panels continue working at 100%. If one panel is damaged all the other panels continue to work. The maximum power is going to be obtained from each of the panels. This is how Firman et al. (2014) indicates that with a centralized inverter, the total power generation of the system can decline drastically if a single panel stops producing power due to a failure or shadow.

Batteries or accumulators: they are responsible for storing the energy that is captured and not used during sunlight hours. In this way, this energy is available at night or at times of lower production. They account for almost half of the budget in an off-grid solar system and therefore it is very important that they are adjusted to the needs. (Auto Solar, 2020)

There are small and economical batteries for more discreet uses and large accumulators for greater needs. Similarly, there are also different types of technologies such as lead acid batteries, AGM batteries, GEL batteries, lithium battery stationary batteries. (Recalde et al., 2015 p. 100) "Batteries are grouped to obtain the working voltage required by the inverter and their capacity must also be in line with the power of the inverter and the use to be given to the system". It must also be ensured that the charge regulator is prepared to work at the voltage of the battery bank to operate...

Materials and methods

The study area of the photovoltaic sizing project is located in the city of Quevedo, parish of 7 de octubre, on D Street, between third and fourth streets. Its geographical coordinates are: -1.041667, -79.473333.

For the simulation of the photovoltaic system, the load profile of the residence of the kW consumed per hour, during the 365 days of the year, is required. For this purpose, 8760 data were obtained and used by HOMER Pro to simulate and find the optimal components.

Global horizontal solar irradiance and temperature data were obtained from NASA's Surface meteorology and Solar Energy (SSE) database and are presented in Table 1and **¡Error! No se encuentra el origen de la referencia.**.

Table 1 . *Global average global horizontal solar irradiance of the study area.*

Month	Clarity index	Daily irradiance (kWh/m2/day)
January	0.414	4.21
February	0.419	4.38
March	0.453	4.76
April	0.457	4.64
May	0.437	4.18
June	0.411	3.78
July	0.409	3.81
August	0.428	4.21
September	0.419	4.32
October	0.381	3.97
November	0.413	4.21
December	0.408	4.09

Result

For the present project, it was decided to carry out two simulations, which will later be compared in order to select the most feasible project:

1. A stand-alone system with generator set
2. A networked system
3. Isolated system with generator set

The components of the isolated system are shown in Table 2

Table 2 . *Components for the isolated system*

Component	Features
Photovoltaic panel Renogy RNG 235P $230 / unit	Power: 235 W Voc: 37.08 V Isc: 8.34 A Type: polycrystalline silicon
Battery Trojan SAGM 12 205 $290 / unit	Voltage: 12 V Capacity: 205Ah @ 20Hr Material: Polypropylene Type: VRLA, maintenance-free Shelf life: +8 years
Inverter Studer Xtender XTS 1200-24 1365 / unit	Nominal battery voltage: 24V Input voltage range: 19 - 34V Continuous power at 25C: 800 / 650VA Maximum yield: 93%. Pure sinusoidal output voltage: 230Vac / optional 120Vac
Gasoline generator PTK GG 1/18220 $290 / unit	Power: 3.3 kW, 6.5 HP Engine: 196 cc 4-stroke gasoline Tank: 15 liters Continuous operation: up to 10 hours

The isolated system design has two generators: the photovoltaic panels with an energy production of 4034 kWh/year and the gasoline generator of 713 kWh/year, representing 85% and 15% respectively. Figure shows that the gasoline generator is mostly used during the months of May, June, July and August, when electricity consumption is much higher due to the use of heating and/or cooling appliances, and therefore the backup generator has to be used.

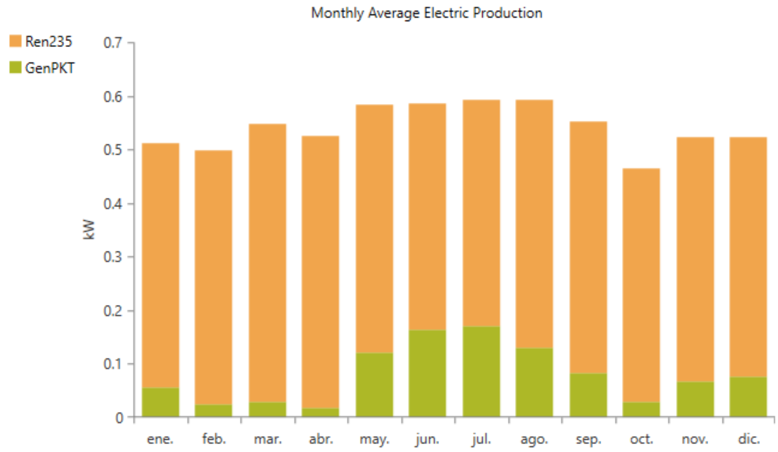

Figure 4. Average monthly electricity production by type of isolated system generation

The solar array consists of 14 panels with a total installed capacity of 3.31 kW, generating an average of 11.1 kWh/day or 4034 kWh/year.

The gasoline generator will have consumed a total of 277 L of gasoline during its 25 years of useful life, works an average of 753 hours per year, has a useful life of 19.9 years and an efficiency of 28.5%, i.e. it only uses that percentage of the fuel energy to transform it into electricity.

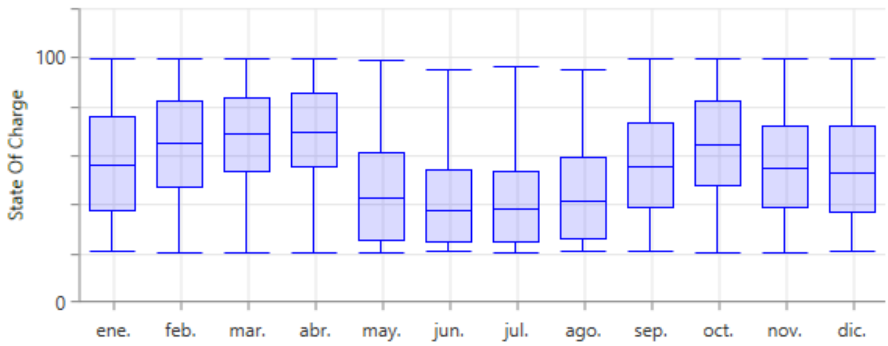

Figure 5. Monthly state of charge of Trojan SAGM 12 205 batteries.

The battery bank is composed of two batteries in series and three in parallel working at a total voltage of 24 V and with a nominal capacity of 12.6 kWh. The system has a total autonomy of 29.3 hours, at a cost of $0.138 per kWh stored and a projected lifetime of 7.53 years. Figure shows the simulation of the monthly state of charge of the battery system, where the charge and discharge limits of the controller were set between 20 - 100%.

Table 3. *Cost of installation, operation and maintenance and salvage value of the system during its useful life as an isolated system***3**

Components	Capital ($)	Total
GenGasolinePTK3.3	$957.00	$3,133.52
Renogy235RNG-235P-60	$3,236.92	$4,635.48
Studer Xtender XTS 1200-24	$2,730.00	$4,506.05
Trojan SAGM 12 205	$1,740.00	$3,257.99
System	$8,663.92	$15,533.05

Networked system

The components of the networked design are shown in Table 4.

Table 4 . *Components for the grid-tie system*

Component	Features
Photovoltaic panel Renogy RNG 235P	Power: 235 W Voc: 37.08 V Isc: 8.34 A Type: polycrystalline silicon
Inverter Schneider Conext SW4024	Nominal battery voltage: 24V Input voltage range: 20 - 34V Power: 3400 W

	Maximum yield: 92%.
	Pure sinusoidal output voltage: 120/240 Vac

The photovoltaic solar panels generate 4013 kWh per year and the grid delivers 2045 kWh/year, representing 66.2% and 33.8% of energy production respectively.

The residence is connected directly to the electricity provider's grid and to the photovoltaic system. The grid will be delivering energy to the house, and at the moment there is enough solar radiation on the photovoltaic panels, the inverter goes to work and delivers energy to the grid, thus reducing the costs in the electric bill since the meters will have the function of measuring the flow of power in and out. In the event that more energy is generated than is consumed, the excess electrical energy will be considered as a credit that will be deducted from the electricity consumption of the following month.

The solar array consists of 14 panels with a total installed capacity of 3.29 kW, generating an average of 11 kWh/day or 4013 kWh/year.

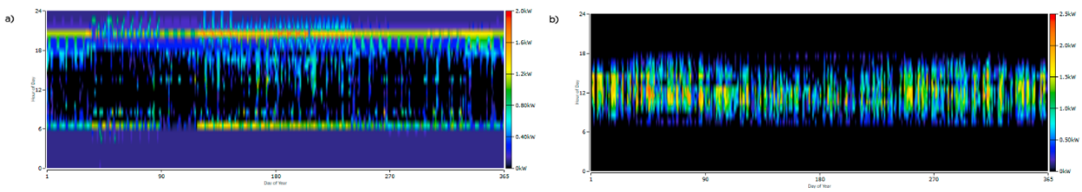

Figure 6. a) Energy purchased and b) energy sold from the grid in the grid-on system.

Figure shows the energy bought and sold by the user in the electric grid. It can be seen that no energy is purchased during the 8 to 18 hours because there is solar radiation and therefore it is generating energy that can be sold or used by the user.

Table 5. *Cost of installation, operation and maintenance and salvage value of the system during its grid-tie system lifetime***5**

Components	Capital ($)	Total
Web	$0.00	$165.35

Renogy 235RNG-235P-60	$3,220.00	$4,611.25
Schneider Conext SW4024	$1,600.00	$2,482.00
System	$4,820.00	$7,258.60

Comparison of results

Table 6presents a summary of the results obtained by simulating in HOMER Pro and a comparison of these two systems.

Table 6 . *Comparative results of the isolated system and the grid-connected system of the project.*

CHARACTERISTICS	ISOLATED SYSTEM	NETWORKED SYSTEM
Components	- 14 RNG 235P panels - 6 Trojan SAGM 12 205 batteries - 2 Studer Xtender XTS 1200-24 inverters - 1 generator PTK GG 1/18220	- 14 RNG 235P panels - 1 Schneider Conext SW4024 inverter
Net Present Value (NPV)	$15,533.05	$7,258.60
Energy produced	Panels: 4034 kWh/year Generator: 713 kWh/year Total: 4747 kWh/year	Panels: 4034 kWh/year Network: 2045 kWh/year Total: 6058 kWh/year
Advantages	- It is independent of the power grid, it	- Much cheaper because fewer components are required

	consumes what the system generates. - Ideal for areas with no access to the power grid - A back-up generator can supply the missing demand	- No batteries required - When the panels do not produce, the electricity supplier supplies the demand
Disadvantages	- The cost of the system is high due to the batteries. - Battery leakage poses high risk to people and the environment - Requires a ventilated space for the battery bank - Excess energy produced is wasted	- Grid-dependent, do not operate during power outages - With no backup generators, you will have no power during an outage.

Final decision

The grid-connected system is the most suitable for this project. The residence is located in the city and has access to the electric grid, the addition of a grid-connected PV system will help decrease consumption and therefore decrease electric bill costs.

Single-line connection diagram

Once the grid-connected system has been selected as the final design for the residence, we proceed to represent the single-line connection diagram in Figure 2of the elements that compose it.

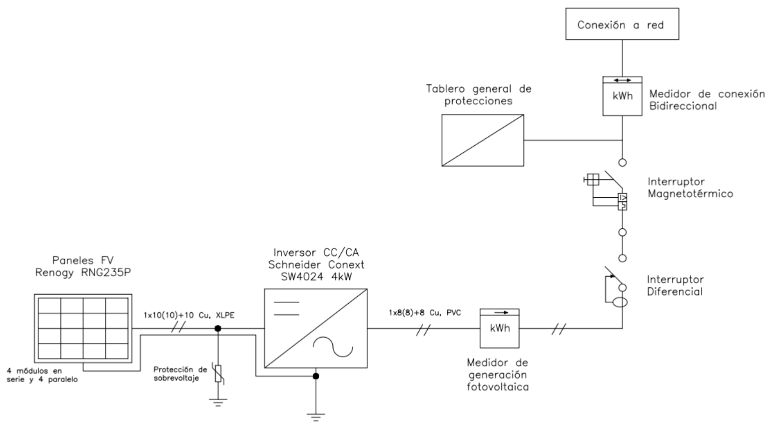

Figure 2 . One-line diagram of grid-connected photovoltaic installation of the residence.

Shadow simulation

The shading simulation performed with the SketchUp Pro software took into account the hours from 7:00 am to 6:00 pm. In Figure 3, it can be seen that the photovoltaic panels are not affected by the shadows of the panels themselves and that their spacing is adequate.

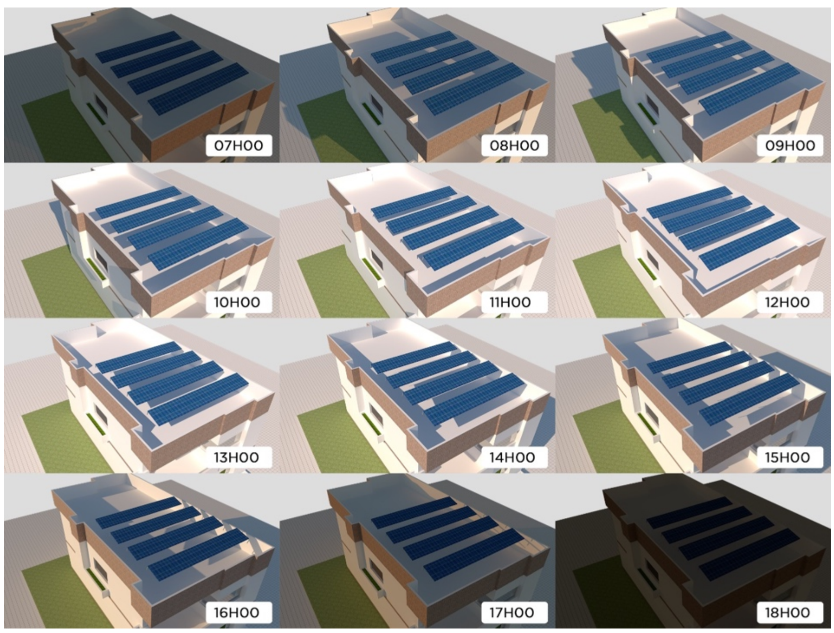

Figure 3 . Simulation of shadows of the 3D model between 7h00 and 18h00 in SketchUp Pro software.

In the design of the isolated system, AGM type VRLA batteries were used for energy storage. Due to the boom of new energy storage systems, it is convenient to perform the economic and technical analysis of these technologies in distributed generation systems such as:

The inertial battery also known as flywheel or flying disk, which store kinetic energy of rotation.

- Supercapacitors
- Thermal storage
- Other types of electric batteries (flow battery, metal-air, lithium-ion, etc.)

For the sake of simplicity, the study was limited to two types of photovoltaic systems. The analysis of a hybrid system, similar to the grid-connected one, but with batteries, could be useful in specific applications.

Conclusions

The choice of a grid-connected photovoltaic system or a stand-alone system will depend on several factors such as economic profitability, the user's needs or the geographical location of the project. Isolated systems are usually expensive, bulky and not very environmentally friendly. Whereas a grid-connected system in most residential homes because they are covered in case the system produces less or more with respect to their different energy needs.

For the design of this project, it was concluded that a grid-connected system was ideal, since its costs are reduced by half with respect to an isolated system, it is located in an urban area with access to the electrical grid, and it reduces the cost of electricity bills. The location of the photovoltaic panels is of vital importance, since their performance is proportional to the amount of solar radiation to which they are exposed, this performance will be affected by the shadows that may be caused by objects and structures near the project area. Through a simulation of shadows in SketchUp Pro, it was possible to analyze that the performance would decrease if placed at a low height, so it was decided to use in an elevated structure in the form of a roof.

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