



Energy Generation System Through a Thermosolar System in Ecuador



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Abstract

The need to obtain sustainability solutions to promote the use of renewable energy, due to the energy problems that Ecuador presents, including power failures, promotes the search for alternatives for energy generation. The objective of the research was to analyze and design an energy generation system through solar radiation. Where the investigative, descriptive, and analytical methodology was used. The result was that the energy generated through a Thermosolar plant can be used to distribute and cover part of the electrical load that exists in the equator. Furthermore, the implementation of this technology could be an efficient and sustainable alternative to conventional systems that depend only on hydroelectric plants and fossil fuels, such as thermal plants.

Keywords

*efficiency;
generation;
renewable sources;
solar radiation;*

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1 Introduction

Ecuador is a country that has great potential in the use of natural resources for energy generation, where the use and implementation of solar energy has increased, especially in cities where its geographical location and the solar radiation that emanates throughout the year allow the use of this type of energy. Ecuador is located in South America, on the equator, so its territory is in both hemispheres, bordering Colombia to the north and Peru to the south and east (Ho et al., 2014).

In Ecuador, currently 92% of energy generation comes from hydraulic plants, 7% from thermal plants, and 1% from non-conventional sources such as photovoltaic, wind, biomass, biogas, and geothermal (Carrillo et al., 2022). Due to current generation problems, the implementation of new generation sources is sought, with a Thermosolar plant as the main proposal (Llanes Cedeño & Barragán Llanos, 2020).

The use of renewable energy for sustainability in the field of energy generation to supply loads in the country is key to being able to maintain development as a country, and thus be able to cover the levels of demand that are currently required within the country (Capel Molina, 2010; Naik et al., 2010). The implementation of this Thermosolar system, as a source of energy generation, will not only complement the flow problems that exist in hydroelectric plants in times when there is no rain since they cover 92% of the energy generated within the country, but it would also demonstrate the viability of the use of renewable energy sources (Salazar Peralta, Pichardo, & Pichardo, 2016).

According to studies of solar radiation in Ecuador, several cities have a high and medium level of solar radiation, such as:

Cities that are in a high level of solar radiation producing 5.0 to 5.5 kWh/m daily, according to (Regalado, Guerrero, Parra, & Salum, 2016) they are: Cotacachi, Otavalo, Tabacundo, Cayambe, Quito, Sangolquí, Azogues, Nueva Loja, the jewel of the Sachas.

2 Materials and Methods

For the investigation, first, the problem that was presented in Ecuador was analyzed and how it affected the generation of energy to supply the energy demand in the country, an analysis of a solution was carried out with which it was intended to increase a source of energy generation to avoid production shortages and energy outages.

The investigative, descriptive and analytical method was applied, so the design of an alternative energy generation system is proposed through the sun's radiation to transform it into energy to create a source of energy generation, taking into account that the proposal provided is supported with all the information that has been obtained through the bibliographic review of various sources.

3 Results and Discussions

The solar thermal energy generation system was carried out considering both the need to increase a generation source due to the high energy demand that currently exists and the droughts that usually occur in non-winter seasons, as well as the specifications of the solar radiation that exists in certain areas of Ecuador (Celador Lera, 2016). Figure 1 shows the process to follow

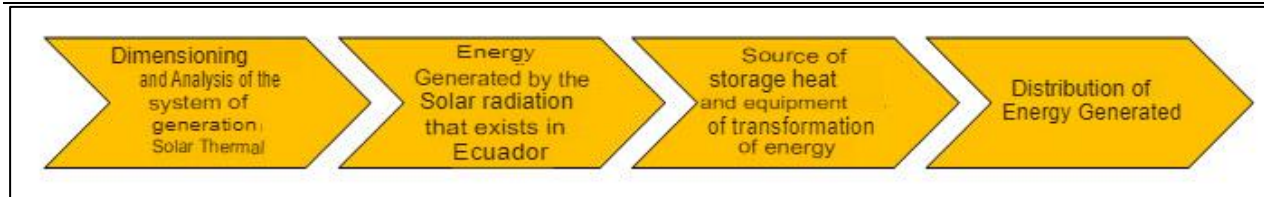


Figure 1. Process to be carried out

Sizing and analysis of the solar thermal generation system: A solar thermal energy generation plant is divided into several components to transform solar radiation into electrical energy (Gómez Chavarry, 2017), so it is characterized by the following components:

Heliostats: They are the equipment that is responsible for giving a certain direction to the sun's rays even when the Earth is in motion. These are made up of several mirrors that reflect the concentration of solar radiation, shown in Figure 2.

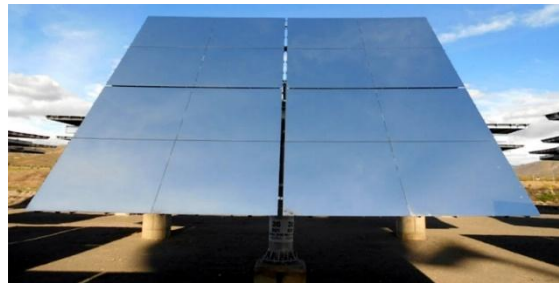


Figure 2. Heliostato

Source: (Patrickson Bórquez, 2019)

Light Receiver: This is where the captured radiation and the heat received from a working fluid arrive from the heliostats to be received the radiation. Figure 3 shows the receiving tower.



Figure 3 Solar radiation receiving tower

Source: (Roldán Millanes & Alonso Romero, 2024)

Figure 4 shows the storage tanks where the hot Salt is stored to later provide the required temperature to the system.



Figure 4. Storage tank
Source: (Boese Franco, 2022)

In Figure 5, the heat exchanger of the system is found; this is responsible for the transfer of the energy absorbed by the sun by the solar collectors to the area.



Figure 5. Heat exchanger
Source: (Acosta Iborra, 2012)

Once the turbine carries out its procedure, it is responsible for causing the generator to produce electrical energy to be injected into the network, as shown in Figure 6.



Figure 6. Steam Turbine
Source: (Vásquez Calero & Mora Robles, 2016)

Solar energy calculation

The energy that can be generated with the solar thermal plant is calculated knowing the average solar radiation that can be generated in Ecuador, which is approximately 5.0 to 5.5 kWh/m² in cities with a higher solar radiation index as shown in Figure 7, which means that depending on the m² that are used for the installation of the heliostats is the amount of energy generated daily. Figure 7 shows the map of the incident radiation at these sites (Orozco Jaramillo & Ordóñez Mendieta, 2020).

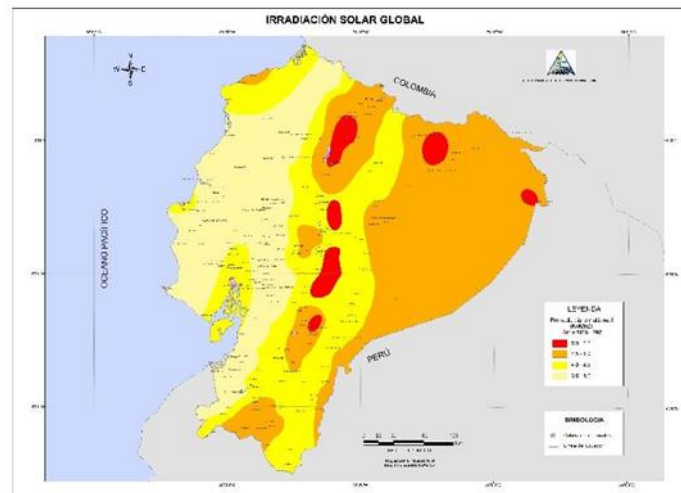


Figure 7. Solar radiation

Source: (Orozco Jaramillo & Ordóñez Mendieta, 2020)

Energy Generated by the Thermosolar plant

The daily energy generated by a heliostat in Ecuador within the cities with the highest solar radiation index of 5.0 to 5.5 hours a day can be calculated according to [Serrano García \(2012\)](#) using equation 1.

$$E_{pr} = R_s \times A_{hel} \times \eta_f \quad (1)$$

E_{pr} → Produced Energy
 R_s → Solar Radiation
 A_{hel} → Heliostat area
 η_f → Efficiency

Taking into account that in cities with a higher incidence of solar radiation, it is 5.0 to 5.5 kWh/m² and the heliostat area is 1 m², and the efficiency is 65%, 70%, and 80%, the following calculations are made:
 For a minimum solar radiation of 5.0 kWh/m² with:

- 65% efficiency
5.0 kWh/m² x 0.65 = 3.25 kWh/m²
- 70% efficiency
5.0 kWh/m² x 0.70 = 3.50 kWh/m²
- 80% efficiency
5.0 kWh/m² x 0.80 = 4.00 kWh/m²

For a maximum solar radiation of 5.5 kWh/m² with:

65% efficiency

$$5.5 \frac{kWh}{m^2} \times 0.65 = 3.58 kWh/m^2$$

70% efficiency

$$5.5 \frac{kWh}{m^2} \times 0.70 = 3.85 kWh/m^2$$

80% efficiency

$$5.5 \frac{kWh}{m^2} \times 0.80 = 4.4 kWh/m^2$$

As shown in Table 1, the results of the generation of a single heliostat with a minimum solar radiation of 5.0kWh/m² and a maximum of 5.5kWh/m² are:

Efficiency	65%	70%	80%
5.0 kWh/m ²	3.25 kWh/m ²	3.5 kWh/m ²	4.0 kWh/m ²
5.5 kWh/m ²	3.58 kWh/m ²	3.85 kWh/m ²	4.4 kWh/m ²

The number of heliostats to cover the generation of a hydroelectric plant. To cover 75 Megawatts per day, it is necessary to know the area where the solar thermal power plant will be built and the size of the heliostat that will fit, depending on the area. Taking into account that the heliostat area has an area of 1 m² and the area for its installation is 1000 m², according to equation 2, the total number will be obtained.

$$N_h = \frac{AND_{dr}}{AND_h} \quad (2)$$

N_h→ Number of heliostats

E_{dr}→ Daily energy required

E_h→ Total heliostat area

With the Thermosolar plant we want to generate a required energy of 75 MW for 24 hours, so equation 3 shows how to know the daily energy required.

$$AND_d = AND_r \times T \quad (3)$$

E_d→ daily energy

I_s→ Required energy

T→ Time

As mentioned above, it is necessary to know the energy generated by each heliostat according to its efficiency and the solar radiation that exists in the area. To know the energy that is produced, equation 1 must be used. To cover the daily energy required, as shown in equation 4, it is necessary to calculate how many heliostats are needed to generate the daily required energy.

$$N_h = \frac{AND_d}{AND_{pr}} \quad (4)$$

N_h→ Number of heliostats

E_d→ daily energy

E_{pr}→ Energy produced

Figure 8 shows the design of the one-line diagram of the Thermosolar plant system.

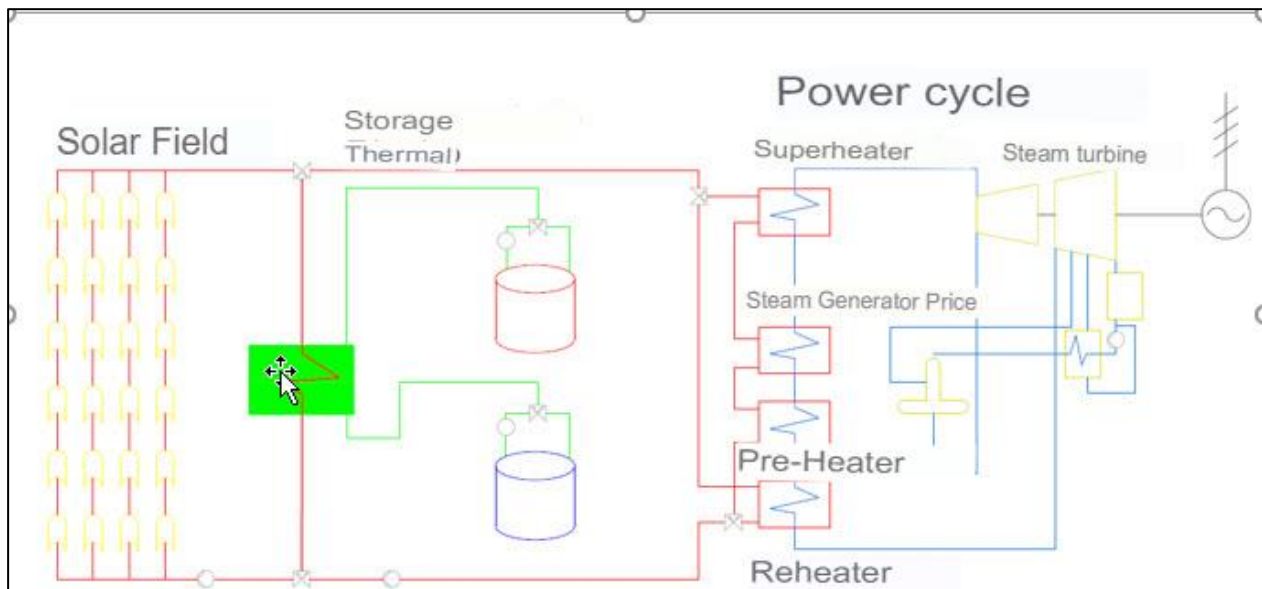


Figure 8. Thermosolar Plant Diagram

The research was designed based on energy problems due to lack of flow in the hydroelectric reservoirs, so energy could not be generated, where the importance of taking advantage of renewable energies and not depending on a single source of energy generation is reiterated, it is based on installing a system that takes advantage of solar radiation to transform it into heat and generate electrical energy to inject it into the network (Wang et al., 2016).

4 Conclusion

The installation of a Thermosolar Plant for energy generation is viable and can replace hydroelectric plants if there is flow in the reservoirs for energy generation. With the implementation of a Thermosolar system and the storage of heat through sand due to its properties of maintaining heat, energy can be generated even when the sun does not rise.

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