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Use of solar panels to improve the quality of electricity supply in a rural locality in the Ancash Region, Peru 2022

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Abstract. - This research study addresses the optimal use of solar panels to improve the quality of electric power service in order to increase the energy supply for commercial use in a Peruvian town in the Ancash region of the highlands, Peru. The applied methodology was applied under the technological cut. The research design was pre-experimental because there was no control group, but the results obtained were quantified. The study was carried out in a rural area with a total of 118 houses. Information on electricity demand in units of kilo watt hours per day for a period of 1 year was used by means of an annual load diagram of the concessionary company Hidrandina. The project requirements included the use of monocrystalline solar panels of 500 Watts and 42.8 volts. After the implementation of the project, the efficiency of the implemented photovoltaic system was analyzed, which yielded a result of 2%. It was concluded that the use of solar panels in rural areas improves the quality of electric power service.

Keyword. - solar panel, electric, service, rural, quality

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I. INTRODUCTION

As the world seeks to transition to more sustainable forms of energy, solar energy has become an increasingly important topic to address in recent years. According to a study by the International Energy Agency (IEA), solar energy is expected to be the world's largest source of electricity by 2050 [1]. Solar panels have the potential to improve the quality of electricity supply by providing a stable source of energy that is less susceptible to interruptions caused by weather events or blackouts [2], [3], [4]. This article explores the use of solar panels as a means of improving the quality of power supply and examines the technological advances driving the growth of solar power.

One of the main advantages of solar energy is that it is a reliable and stable energy source [5]. Unlike other energy sources, such as fossil fuels, solar panels do not rely on a finite resource that can be depleted over time, making solar energy a sustainable and long-term solution to meet energy demand. In addition, solar energy sources reduce the carbon footprint by 45% unlike other energy sources that cause environmental damage to the air and the ecosystem, in the case of the implementation of an energy storage source the reduction increases to approximately 85%. [6]

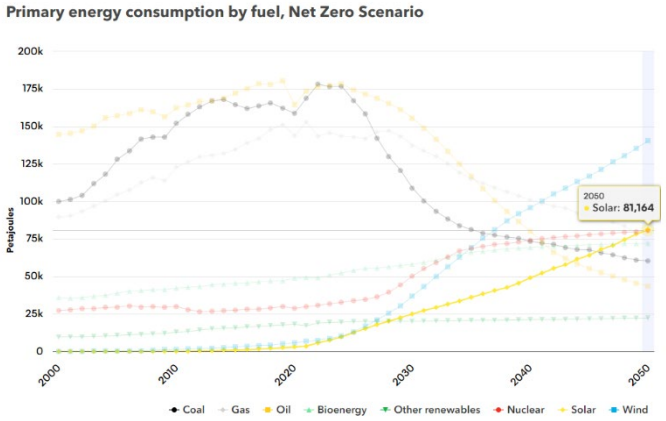

Fig 1. Projected energy generation in Latin America for the year 2050 [7]

In addition, solar power can help reduce pressure on the electric grid during peak demand hours, as well as provide backup power in the event of a blackout. These advantages have made solar power an attractive option for residential and commercial customers.

To reforce the idea of the benefits of the use of solar panels, we should mention the impact it has on scientific publications in high impact journals that are positioned in the best scientific databases worldwide. This is the case of the Scopus database, in which, through a brief bibliometric analysis, significant amounts of publications are obtained over the years, among the metadata analyzed by the Bibliometrix software, the following data stand out (see Fig. 2):

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Timespan: 1990 to 2023
Number of documents: 381
Type of documents: Original articles of journals

En la figura 2 se puede apreciar el incremento progresivo año tras año, coincidiendo en que a la actualidad existen más investigaciones para la mejora, no solo de diseño de captadores de energía solar como las celdas solares, sino de la aplicación en diversos escenarios alrededor del mundo. Se ha considerado

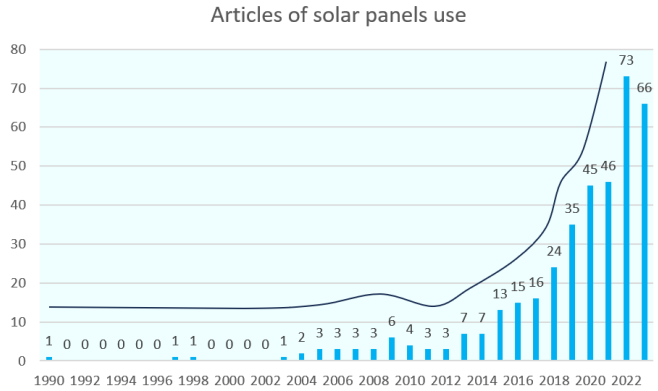


Fig 2. Evolution of scientific production articles from 1990 to 2023

From the information analyzed, trends in topics are obtained, being the niche topics (see Fig. 3):

- Electrification
- Microgrid
- Demand response
- Levelized cost of energy

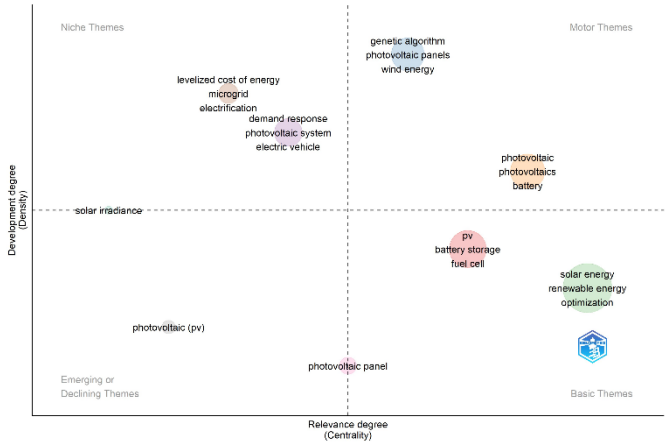


Fig 3. Thematic map of solar panel´s uses trends

The use of solar panels in the town of Pararin, district of Pararin, province of Recuay, department of Ancash, Peru, has designed the construction of a photovoltaic solar field of nominal power of 70 KW, it has been determined the use of solar panels AUTOSOLAR model of 500 Watts with 42. 8v, installation of three inverters of 25 kW, three-phase with charge controller functions of the battery bank, a main feeder circuit is designed that injects to the network of the existing general board, However, the current power supply is unstable due to the characteristics of rural electrification, with interruptions of electrical service, failures due to atmospheric phenomena, lack of cleaning of the easement strip and low quality of service in terms of voltage and variable frequency. [8]

The proper use of solar panels strengthens and improves the quality of electrical service, achieving a more reliable electrical system. The research establishes the calculation of the energy demand, for which a sample survey has been designed to 80 houses of the 118 existing in the town center, in the special loads the necessary data of the power and energy demand in the 12 months of the year is taken. [9]

II. Methods

According to the characteristics of the research, it is classified as quantitative, applied and technological, since it directly addresses the social challenges within a specific sector by taking advantage of modern knowledge and advances in the use of solar panels.

The research design is pre-experimental, focused on the optimal use of solar panels in the town of Pararin in the province of Recuay, department of Ancash to improve the quality of electricity supply.

A. Equipment

Solar panel.- Solar Panels Sunlight emits photons, when hitting a semiconductor (the most used is silicon), these photons provide sufficient energy to the valence electrons (last level of electrons), this is achieved by breaking the bonds and the electrons are free to circulate through the material, the cell itself is manufactured by creating a layer of n-type silicon and another layer of p type silicon joined by a np junction, by the effect of photons, electron carriers and hole carriers are generated, which travel to the junction where they are separated and the electrons are attracted by the holes, generating a voltage differential and electric current flows, this is a photovoltaic cell, the installation of several photovoltaic cells in series and / or parallel constitute a photovoltaic solar panel. [11]

TABLE I
Features of the AUTOSOLAR solar panel

Technical data	Values
Peak power (Pmáx)	545 W
Voltage at maximum power (VMPP)	41,80 V
Intensity at maximum power (IMPP)	13,04 A
Open Circuit Voltage (VOC)	49.75 V
Short-circuit intensity (ISC)	13.93 A
Eficiencia del panel	21.1%

Batteries.- are therefore the solar storage system par excellence. Through their use, energy independence is obtained by being able to accumulate electrical energy, thus allowing the maximum use of solar energy.

B. Population and sample

The population was 118 households in the Pararín population center, in the application of probability sampling with a confidence level of 95%, 80 households were selected. The following public institutions were included in the households:

- District Municipality
- 01 Educational Center
- Catholic Church
- 02 Health centers
- 01 multi-sports complex
- 02 pumping centers
- 02 workshops (01 Carpentry and 01 Structure Factory)

B. Place of study: The research was carried out in the town of Pararin, located at 3380 meters over the sea level, with coordinates (10°02'59" S/-, 77°39'12" W/-), the location placed in Google Earth, is shown in Fig. 4.

Fig. 4. Location of Pararín village center in Google Earth.
Source: Own elaboration

C. Techniques and instruments for the collection and processing of information: The information on the use of electrical appliances to determine the demand for electricity in the town of Pararín was collected through a survey, considering the number of homes, the electricity consumption of each household or institution and public lighting according to the following detail (see Table 1):

TABLE 2
SURVEY FOR THE COLLECTION OF ELECTRICITY CONSUMPTION

Electrical Device	Power (kW)	Quantity	Daily use (Hours)	Monthly usage (Days)	Total (KWh/mes)
Focus					
TV					
Sound Equipment					
Blender					
Laptop/PC					
Total					

Source: Own elaboration

For the records of the amount of energy supplied by the concessionary company (Hidrandina), documentary information was collected from INEI, SENHAMI and OSINERGMIN, this information was used in order to improve the understanding of the operation of the rural electrical infrastructure of the town center, as well as the attributes of the energy supply and public lighting.

The information was processed using Excel to obtain the electricity demand of the Pararín town center.

III. RESULTS

Electricity demand: According to the results of the survey, we can obtain the electricity demand in the critical month (February 2022) in kWh per day, during the 12 months of the year, using the annual load diagram in the 12 months of the year according to the information obtained by the concessionaire (Hidrandina) and making use of the Excel spreadsheet.

The results of the survey showed the required electrical energy consumption in KWh during the 12 months, where it was observed that the critical month of consumption was February 2022, as shown in Table 3.

TABLE 3
CALCULATION OF ENERGY PER MONTH

Month	Available solar power (RD)	Power consumption (ED)	Ratio (ED/RD)
January	4,2	174,12	41,46
February	4,2	194,61	46,34
March	4,1	169,98	41,46
April	5,1	167,07	32,76
May	4,8	106,13	22,11
June	4,3	179,07	41,64
July	5,6	149,25	26,65
August	6,5	106,13	16,33
September	6,7	125,09	18,67
October	6,5	120,23	18,50
November	6,5	108,81	16,74
December	5,5	167,49	30,45

With Table 2, above, the required power could be calculated with the following formula:

Considering that the critical month is February, then the calculation of the value of:

$$E_d = 194.61 \frac{kWh}{día}$$

Therefore, the Trina TSM-DE-15MC11-500 solar panel, which has 500 WP (peak power) and 42.8 V, was selected. The theoretical power without losses was calculated by applying the following formula

$$P_t = \frac{Ed}{HBS}$$

Where:
Pt: Theoretical power without losses
Ed: Energy consumption in kWh/day
HBS: peak solar hours

We obtain:

$$P_t = \frac{194.61\ \text{kWh}}{4,2h} = 46.34\text{kW}$$

Subsequently, the peak power of the generator was calculated with the following formula:equation 4 states:

$$P_{pgenerador} = P_t\left(f_{pp}\right)\left(f_{pinversor}\right)\left(f_{pdiseño}\right)$$

Where:

- Ppgenerator: Peak power of the solar generator (watts)
- fpp: Loss factor of the panels equal to 1.1
- fpinversor: Three-phase inverter loss factor 1.1
- fpdesign: Design factor 1.25

By replacing the values, the nominal power of the photovoltaic generation field was obtained as:

$$P_{pgen} = P_t(f_{pp})(f_{pinv})(f_{des})$$
$$P_{pgen} = (46,34\,\text{KW})(1,1)(1,1)(1,25)$$
$$P_{pgen} = 70\text{KW}$$

We developed:

$$P_{pgenerador} = 46.34kW\left(1.1\right)\left(1.1\right)\left(1.25\right) = 70kw$$

The nominal peak power of the photovoltaic generation field is 70 kW. Considering a power factor: 0.8 (inverter characteristic). The number of panels is calculated with equation 5:

$$N = \frac{P_{pgenerador(w)}}{P_{pp(w)}} + 1$$

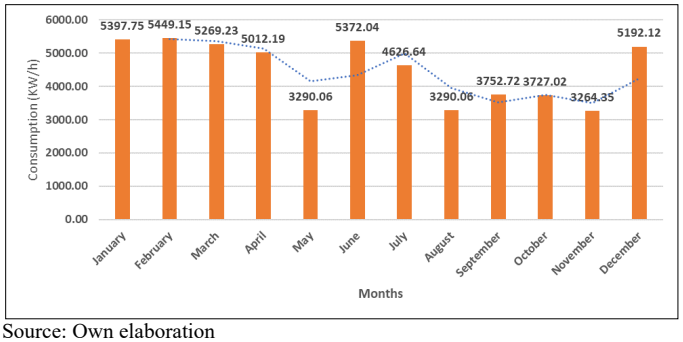
We develop:

$$N = \frac{P_{pgen}(W)}{P_{PP}(W)} + 1 = \frac{70000}{500} + 1 = 141$$
$$N = 144$$

The present calculation is a single iteration, so we use the PVsyst 7.2 software, which is good at performing several iterations, giving us the following values:

- Nominal power of the solar field: 75 kW
- Number of panels: 52 per group (Trina Solar panel model TSM-DE-15M-500)
- Number of groups: 3
- Power of each inverter: 25 KVA
- Power factor: 0.8
- Number of inverters: 1 per group, total 3 inverters

A multiple number of 4 per excess was chosen to supply the possible peaks of consumption, establishing 144 solar panels.



Source: Own elaboration

Table 4 shows the projection of potential customer demand.

TABLE 4
DEMAND FORECASTING WITHIN THE PROJECT LIFE CYCLE

Year	Time	Proyected Demand (KW/h)
2023	1	194,61
2024	2	195,49
2025	3	196,37
2026	4	197,25
2027	5	198,14
2028	6	199,03
2029	7	200,83
2030	8	201,73
2031	9	202,64
2032	10	203,55

Source: Own elaboration

IV. DISCUSSION

In our approach it is observed that the stability and robustness of the power supply is due to the design of the solar photovoltaic plant, since in this way the maintenance and operation of the supply is centralized in the control room, in addition the system has a battery bank that provides stable energy at night and cloudy hours, this is achieved thanks to the technology of having a single solar inverter of 25 KVA power. [12]

The present study has the goodness of being ahead of the future in the sense that it is prepared for the distributed generation of electric energy, which in fact is the future of energy in our country. [13]

Also, by offering an installed power that exceeds the current energy demand, it drives the acquisition of electrical and/or electronic devices to improve the quality of life of the villagers and that some farmers can acquire machinery to transform their crops into higher value-added products. [14]

The multiplier effect in this type of installation will occur, since the neighboring localities can also solve their current problem by installing small photovoltaic solar energy plants and thus achieve a development of the countryside through the technology of transforming agricultural products into processed products. [15]

n addition, the present study establishes that the execution of the project has financing from the rural community of Pararín, then it is feasible and results in an economic benefit for the investor and the return of his investment.

The global trend is the use of renewable energies, so the use of solar panels is environmentally friendly.

Renewable energy sources, such as solar energy, are becoming increasingly popular around the world as a way to reduce emissions and mitigate the effects of climate change. Solar panels are a clean, sustainable and widely available form of renewable energy, and by using them to generate electricity we can reduce our dependence on non-renewable sources such as fossil fuels and nuclear power. They are also environmentally friendly because they produce no greenhouse gases or air pollutants when in operation. They obtain their energy from the sun, which is a clean and renewable source. This makes solar energy a great option for reducing greenhouse gas emissions and combating climate change. Solar energy can help reduce the amount of environmental pollution we produce, such as that caused by oil spills or coal mining. By using solar energy instead of these other sources of pollution, we can help protect natural habitats and ecosystems from the negative effects of pollution.

Renewable energy sources, such as solar energy, solar energy is positive because it is a renewable energy source that can help reduce our environmental impact. As the technology and cost of solar panels continue to improve, solar energy is likely to play an increasingly important role in meeting our energy needs in an environmentally friendly way.

V. Conclusions

Solar energy has the great advantage that the sun provides an inexhaustible source of energy. The installations for its use do not pollute the atmosphere, do not produce greenhouse gases or water pollution. In addition, it does not produce noise pollution, since its generation is silent.

In the installation of solar panels, it is advantageous to have a small solar photovoltaic plant with a control center and grid injection, compared to an isolated and independent photovoltaic system for each house, for example, maintenance can be systematized and programmed both in the predictive and corrective case.

The management strategy consists of registering the rural community of Pararín as a single customer with the concessionaire Hidrandina and obtaining the MT2 tariff, medium voltage 10,000 volts, since it is an economic tariff, so with the programming of the inverter it will be possible to pay practically the minimum in consumption from the grid.

Using solar panels to generate electricity can be a promising solution for both the environment and consumers. Solar power is reliable and cost-effective, and provides a stable source of energy that is less susceptible to interruptions caused by weather events or power outages. In addition, the use of solar energy can help reduce carbon emissions and reduce dependence on finite resources such as fossil fuels.

Solar panel technology has evolved over the years to become more efficient and practical, making solar energy more accessible and attractive to residential and commercial consumers. Governments and private organizations have put in place policies and incentives to encourage solar adoption, including tax credits and rebates. This makes solar a viable option for many individuals and businesses.

Despite the many advantages of solar energy, its widespread adoption still faces some hurdles. One of the main ones is the initial cost of installation, which can be a major hurdle for many consumers. However, as technology advances and costs decrease, solar energy is becoming more accessible to a greater number of consumers.

Overall, solar panels are a promising solution that offers many advantages for both the environment and consumers. As the world continues to seek sustainable energy solutions, solar energy is likely to play an increasingly important role in meeting energy demand while reducing the carbon footprint of electricity generation. Overall, the use of solar panels to improve the quality of electricity supply is a promising solution that offers many benefits for both the environment and consumers. As the world continues to search for sustainable energy solutions, solar energy is likely to play an increasingly important role in meeting energy demand while reducing the carbon footprint of electricity generation.

VI. Recommendation

The planning of solar energy projects is recommended to obtain greater coverage in areas that require access to electricity. In the case of research in rural areas, a spatio-temporal study is recommended to analyze the availability of natural resources, in the case of solar panels, the levels of solar radiation throughout a day and what is its behavior throughout the months of the year.

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