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Implementation of Topologies in Systems Public Lighting with Micro-Inverters and Injection to the Grid with Solar Energy Photovoltaic Using Etap

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Abstract*– In grid-connected photovoltaic systems (SFCR) in public lighting, several studies need to be carried out, in various conditions. This study in the city of Puno makes a contribution to the use and massification of distributed generation in public lighting systems in low voltage balanced systems. The objective is to analyze the performance in the connection to the grid of the photovoltaic system in public lighting and to be able to verify the electrical parameters such as: power factor, voltage and power generation to inject, considering different topologies and then carry out the treatments through simulations with The ETAP software, The study used polycrystalline photovoltaic panels (SOLAR MODULE EGE-200P-72), micro inverters (MICRO REPLUS) and luminaires with a load of 70 W. The results of three SFCR topologies were analyzed using the ETAP software. Two scenarios were carried out with different irradiance levels (1000 and 500 W/m^2), from which the results were verified for electrical parameters such as voltage drops, harmonic distortion THD and frequency. In relation to the recommended topologies to analyze the viability of implementing a 1.91 KVA public lighting system connected to the electrical grid, a feasible option for our region is presented. This study will be integrated into regulations related to power generation through grid-connected photovoltaic systems. In conclusion, the results of the study demonstrated an improvement in the reliability of the electrical power system in public lighting in the city of Puno thanks to the implementation of photovoltaic systems connected to the grid. This translates into benefits such as greater power generation, better power factor, voltage stability and energy savings.

Keywords*-- Public Lighting, Solar Energy, Micro Inverter, Topology and electrical grid.

I. Introduction

To satisfy a constantly growing demand for energy (increase in population and consumption habits), it is possible to achieve this objective through the application of renewable energies; it is important to know fundamental concepts [1]. In this context, photovoltaic solar energy stands out among the source of solar energy, as it is considered an inexhaustible source of generation. Studies show the diagnosis and performance of solar panels [26], they also show a diagnosis in a system with solar panels and batteries [12]. The solar incidence and the hours of day on photovoltaic solar panels are taken into account [8]. Also in photovoltaic technology, simulations with the PVSYST are used to cover energy demand [31].

Photovoltaic applications have been spread in different areas of industry, water distillation by solar energy [20], water pumping, collective use applications [36]. They are promoted for use in hybrid electric vehicles [1], in many countries the purchase of this technology in solar energy generation systems is being facilitated [13]. International experiences such as in Japan, that the use of photovoltaic solar energy in photovoltaic generation was growing due to various government incentives [37]. There are also studies that calculate the return on investment to support the design of photovoltaic installations [25]. Great progress has also been made in the study of ultracapacitors in autonomous photovoltaic systems [2].

The present study in a specific case will be based on the photovoltaic systems connected to the grid (SFCR) today they are studying, analyzing, carrying out projects, in different countries, the characteristics of the energy quality system are presented where it is concluded that systems can be used to implement distributed generation [6], it is necessary to compare existing regulatory frameworks in other countries to have an ideal working model [18]. An SFCR consists of a micro inverter, or inverter, the study shows a single-phase inverter connected to the grid from renewable sources [30], there are different topologies in the design of micro inverters with and without power link. direct current [11]. Use of a boost converter (Boost) and a single-phase DC-AC inverter design [3].

By implementing this technology, it is possible to increase the generation and injection of energy into the network and improve the impact on billing [17]. Various projects consisting of public lighting installations powered by solar energy under criteria of the existing technological capacity in the market and compare the necessary requirements for public lighting of streets and roads [24]. Other public lighting studies use an LED lighting device [9]. Thorough investigations focusing on LED lighting of its current state with respect to conventional luminaires [4]. The aspects of light sources and the visual demand of users have been analyzed from a social perspective [35].

Grid-connected photovoltaic (SFCR) systems are highly adaptable to existing electrical infrastructure, allowing the management of various power capacities and voltage levels. Its configuration can be adjusted according to the specific requirements of the electrical network. This current analysis confirms the feasibility of using grid-connected photovoltaic systems in public lighting. A balanced simulation has been carried out using ETAP software, and this presents us with a relevant option to implement SFCR in our region. The proposed topologies could serve as a reference for local regulations and accelerate their inclusion in legislation. The main objective of this research work was to propose the use of different configurations in public lighting systems that use micro inverters to integrate photovoltaic solar energy into an electrical distribution network.

II. METHODOLOGY

Scope or Place of Study: The research site included a substation identified with the code and label 105015 on Avenida Simón Bolívar, located in the district of Puno, province of Puno, in the department of Puno. This location is precisely at the geographical coordinates of latitude -15.8329, longitude -70.0223, and at an altitude of 3870 meters above sea level.

Study period or sampling frequency. For the sizing of SFCR, a review of the main methodologies and the regulations with which it must be carried out was carried out [33], so that it does not distort the network of a period of the last ten years of the various methodologies applied.

To determine the factors that have the greatest significant effect, regarding the variation of voltage, frequency, THD and see the behavior of the network with SFCR. The power consumption of the 70 W luminaires was taken into account, in a balanced, single-phase network. Daily irradiance data was taken from the NASA page. The reviewed bibliographies of various authors, comparative analysis of the selection of application methodologies for correct sizing considering, mainly, that it does not distort the conventional network. As materials and instruments, the following were required: The low-voltage, single-phase network, direct current thermomagnetic switch, notebook; pole records (nodes). In this section, using the ETAP software, the appropriate model could be optimized.

The variables studied and analyzed were: topologies are shown in balanced radial systems in order to improve the reliability of the network, power factor, THD. were used. The variables studied are frequency and THD alterations in the three scenarios, each with its own voltage levels. Finally, the SFCR in Public Lighting systems, analyzed in the three scenarios, with optimal parameters for the entire system, enters the electricity generation regulations.

Avoid combining SI and CGS units, such as current in amperes and magnetic field in oersteds. This often leads to confusion because equations do not balance dimensionally. If you must use mixed units, clearly state the units for each quantity that you use in an equation.

III. RESULT AND DISCUSSION

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The calculation of the size of the photovoltaic system connected to the grid was carried out to cover the first two sections of Avenida Simón Bolívar, located in the city of Puno. to which it delivers energy to the main distribution board, constituting a photovoltaic system connected to the Grid (SFCR), which is a possibility that contributes to the configuration of a distributed generation electrical system [29].

For the study and analysis, three topologies were designed in the public lighting system [15], using: 200 W photovoltaic panel, and a micro inverter, which would be connected to the network according to the topologies connected to the Grid.

A. *Solar Panel Calculation*

The objective of this section is to evaluate the sizing of the photovoltaic generator [33] that the system as a whole need. The solar radiation recorded for the town of Puno is presented, with a latitude of -15.8329, longitude of -70.0223, and an altitude of 3870 meters above sea level, highlighting that it reached its maximum point during the month of November in the year 2020 as shown in Fig. 1.

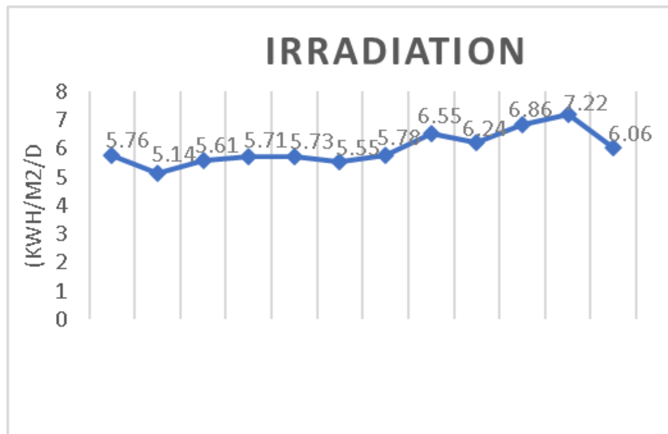

Fig. 1 Average irradiation 2020

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The data shown in the calculation are used from the year 2020 on the NASA page, other studies show the use of software that provides geometric data, the program shows versatility in use [16]. It is important to evaluate the performance of solar panels because they determine the operating curve of the panels and be able to validate their operation [28].

The power of this Polycrystalline photovoltaic solar panel model is based on the SOLAR MODULE 72 CELLS model with a power of 200W, and a short circuit current of 11.41A, as show in Table I.

TABLE I
PHOTOVOLTAIC SOLAR PANEL EGE-200P-7

Parameters Electrical STC	**description**
(P_{max})	200 W
(I_{mp})	10.45 A
(V_{mp})	19,14 V
(I_{sc})	11,41 A
(V_{OC})	23,31 V
Temperature Characteristics	
temperature coefficient of (Pmax)	-0.396%/°C
Temperature coefficient of (Voc)	-0.31%/°C
Temperature coefficient of (Isc)	+0.06%/°C

The model used is a polycrystalline photovoltaic solar panel, compared to a study [14] where it helps predict the output behavior of a photovoltaic panel mainly due to climatic conditions, in another investigation with a SAM computational tool (system Advisor Model) uses the monocrystalline photovoltaic panel and highlights the inclination and orientation [19].

- Optimal inclination:

$$\beta = 3.7 + 0{,}69\emptyset \quad (1)$$

From the data shown in the Annual average irradiation table, on a horizontal surface:

$$6{,}0175 Kwh/m^2 dia \quad (2)$$

$$Ga(0^0) = 6{,}0175 * 365 días \quad (3)$$

- Calculation of the value of the annual Global Irradiation, with an optimal annual inclination

$$Ga(\beta) = \frac{G_a(0^0)}{1-4{,}46.10^{-4}.\beta - 1.1\cdot 10^{-4}.\beta^2} \quad (4)$$

- peak power of each module is

$$p_P = I_{mp} x V_{mp} \quad (5)$$

- energy supplied by generator in a day

$$E_G = \text{HSP } x P_P x N_T x \eta_m \quad (6)$$

TABLE II
CALCULATION RESULTS

Equation	Results
Inclinatión optimal	$\beta = 15°$
Data obtained from the average annual irradiation.	$Ga(0º) = 2196.38 \frac{Kwh}{m^2}$
annual global irradiation, with an optimal annual inclination	$Ga(15º) = 6{,}22 KWh/m^2 dia$
Module peak power	200.013W
Energy supplied by the generator in a day.	$E_G = 1119{,}67\ KWh/dia$

The results shown with respect to the average annual irradiation table, with an optimal average inclination of 15 °, with a peak power in each module of 200W, with an energy supplied by generator of 1119.67*KWh/día* What will the module use

B. *Micro-Inverter Calculation*

The input power of the Micro-Inverter is 270 W in direct current and an output power of 225W in alternating current and an average daily load power of 70W as show in Table III.

TABLE III
CARACTERÍSTICAS DO MICROINVERSOR MICRO REPLUS 250

dc input	
Generation (270Wp)	270
Icc(A)	14
Voltage (V)	55
MPPT(V)	22-45
ac output	
(W)	225
(V)	208
(Hz)	60
THD	<4%
(cosϴ)	<0,95
η	96,3%
degree of protection	IP66

considered power 70W	HSP=6,22 KWh/m^2.día

TABLE IV
CONFIGURAÇÃO COM NÍVEIS DE IRRADIAÇÃO 1000 W/m2, 500 W/m2, FREQUÊNCIA E DISTORÇÃO HARMÔNICA TOTAL (THD)

topology		KW	KVAR	KVA	THD (%)
irradiance, 1000	topology 01	3.02	0.103	3.021	-
	topology 02	3.22	-0.448	3.25	-
	topology 03	3.02	-0.264	3.03	-
irradiance, 500	topology 01	0.527	-0.327	0.62	-
	topology 02	0.619	0.529	0.814	-
	topology 03	0.527	-0.437	0.684	-
frequency addition, THD	topology 01	4.45	0.579	4.48	0.019
	topology 02	4.63	0.02	4.63	0
	topology 03	4.44	0.207	4.45	0

The micro inverter used in this study has attributes that are compatible with the photovoltaic panel. Previous research indicates that an improvement in efficiency is achieved when using a PV array with micro inverters compared to a centralized inverter array. [10]. One option to consider is the incorporation of micro inverters in the conversion process from direct current to direct current (DC/DC), its distinctive characteristic being the increase in the amount of active energy [34].

Micro Inverter Features

1) The maximum input current that the inverter must be able to withstand, the short circuit current of the panel.

$$I_{sc} = 11{,}41A;\ I_{sc} = NpxI_{5C} \quad (7)$$

Inverter input maximum input current 14A, Micro Replus-250

C. Verification of Results

The study carried out considers topology 01 as shown in Fig. 2, with connection of one photovoltaic panel per node. The result that was considered with an irradiance of 1000 W/ m^2,and 500 W/ m^2, in Table IV shows the appearance of THD, as long as a micro inverter is altered.

The results presented contribute to increasing the reliability of the electrical network. A similar study shows [18] by using it as a photovoltaic generator connected to the low voltage network, energy balances can be carried out and can demonstrate this reliability of the network.

The results show a reduction in photovoltaic energy production due to lower irradiance, such as the energy evaluation of active power, reactive power, apparent power. In a similar study [6] the amount of energy injected and its characteristic performance are verified, as long as appropriate inverters are used.

Results show us an alteration of THD and the frequency remains constant, considering that the product of this variation is because we generate a failure in one of the micro inverters. A similar study shows that with the use of technological innovation through the introduction of photovoltaic technology connected to the low voltage network [27], quality improvement can be achieved.

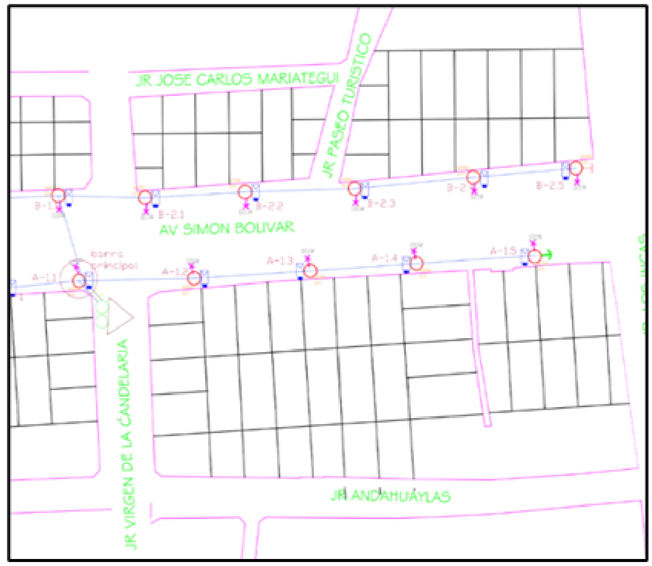

Fig. 2 Load distribution plane, topology 01

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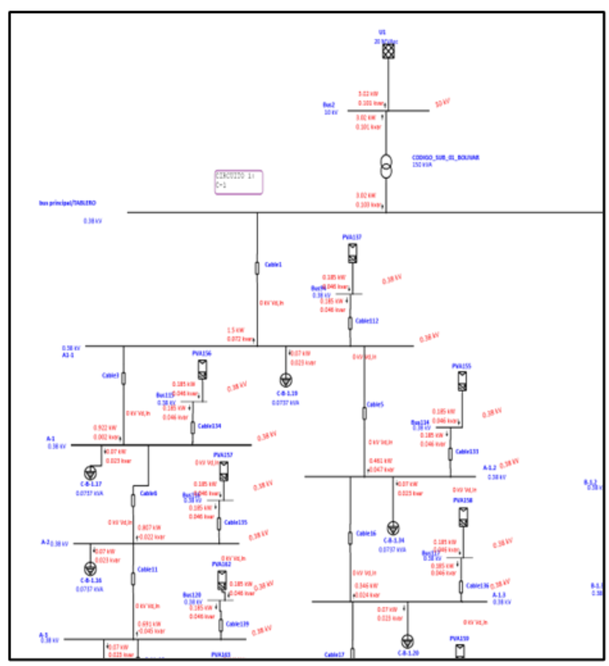
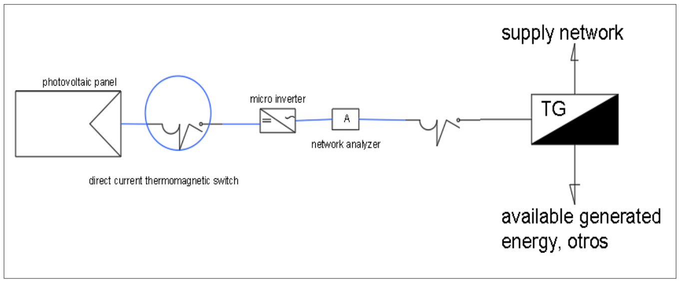


Fig. 3 Single-line diagram ETAP software Irradiance_topology_01_1000W/m2



. Fig. 4 electrical connection diagram

In Figure 4 you can see the electrical connection diagram, in sequential order as follows: photovoltaic panel, direct current thermomagnetic switch, micro inverter, network analyzer, connection board where the generated energy is available.

IV. CONCLUSIONS

This study has highlighted configurations in public lighting systems by implementing grid-connected PV systems in low-voltage networks, particularly in balanced radial systems. The relevance of the improvement in electrical aspects is highlighted, such as the power factor, the voltage level and the increase in energy generation for injection into the network, in addition to the energy savings achieved thanks to photovoltaic technology. with microinverters. And for other investigations, an unbalanced system with inductive loads can be considered [23].

Of the SFCR topologies are shown in Fig. 3, using the ETAP software, considering the following: two scenarios were made with irradiance of (1000 and 500) W/m^2, where the reliability of the network in the nodes improves in comparison to the proposed network study 1.91KVA. A frequency and THD study were also done, where there are no alterations.

The results obtained demonstrate an improvement in the reliability of the electrical system of the public lighting network with regard to active power, reactive power, voltage, frequency and THD. A study managed to estimate the fluctuations of photovoltaic production in the energy quality in a low-voltage network through load flow [5]. Perhaps this remains for future research, as was also studied in another research. the conversion efficiency of inverters [7] in grid-connected photovoltaic system.

According to the configuration presented to analyze the 1.91 KVA public lighting network connected to the network, a feasible option is identified for its implementation in our region. This study could be incorporated into regulations governing electricity generation through grid-connected photovoltaic systems.

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